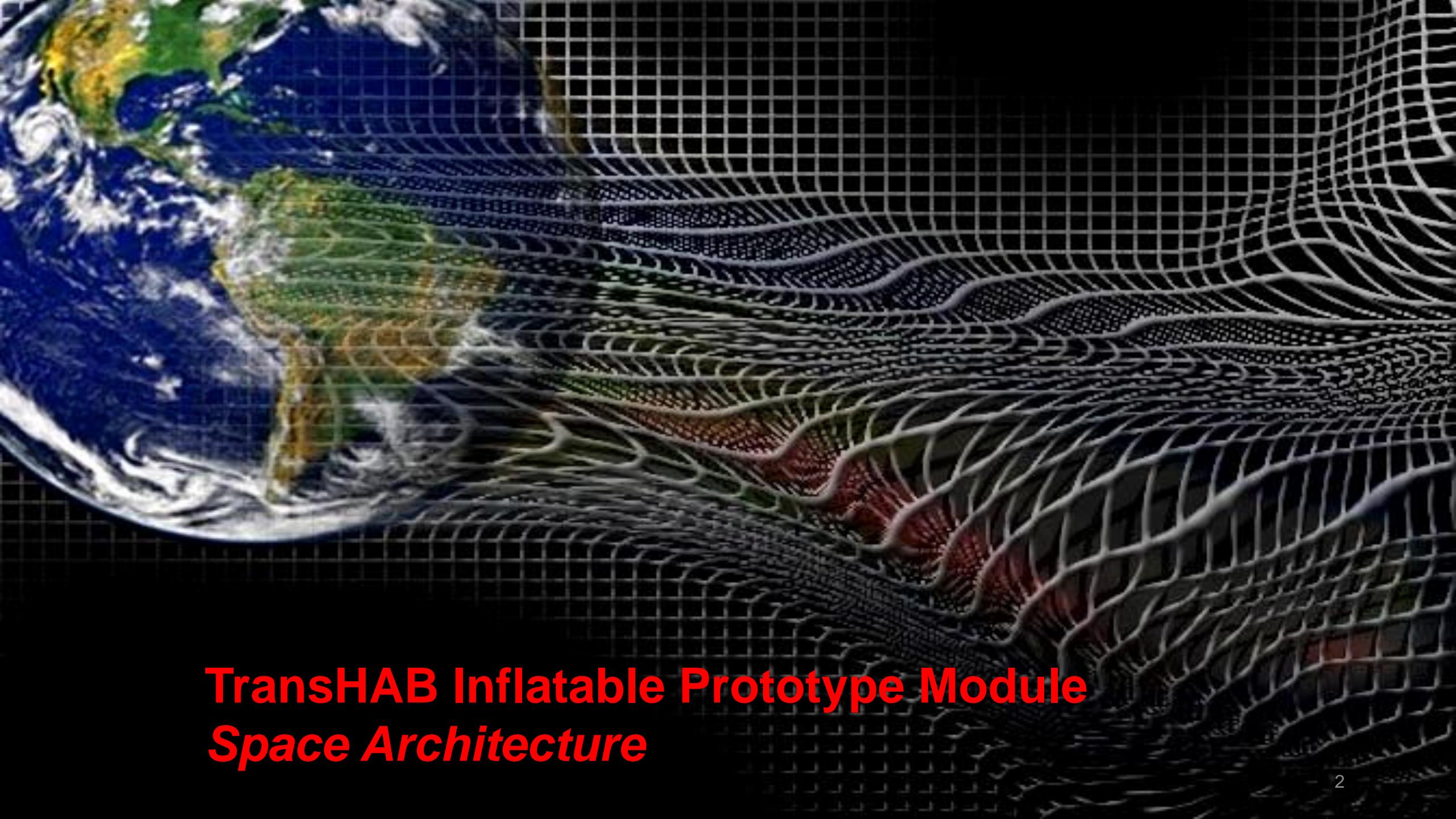


# University of Houston

# SPACE ARCHITECTURE

Case Study: TransHab Inflatable Habitat

*Kriss J. Kennedy*  
**Space Architect**  
*September 28, 2016*

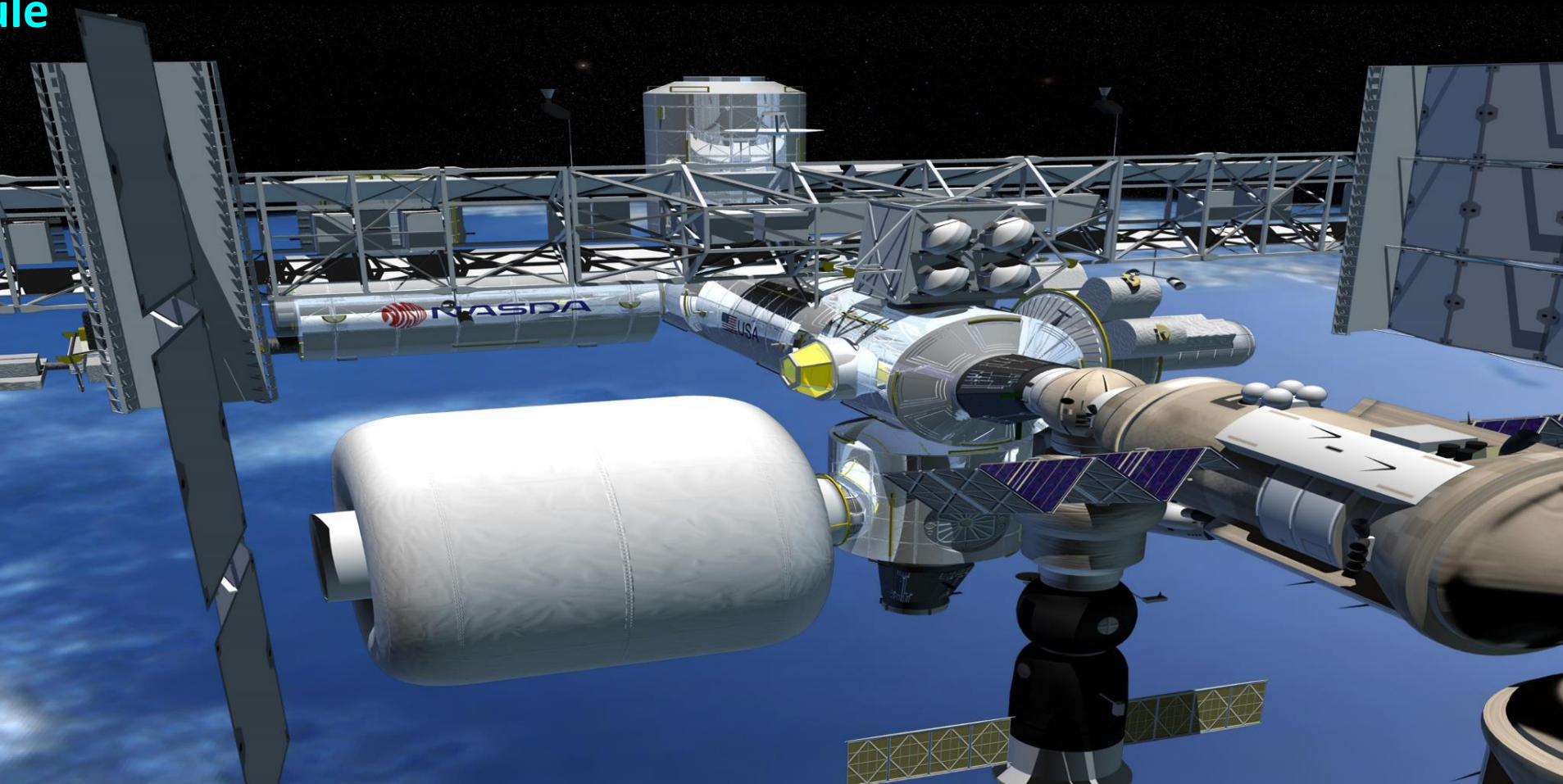


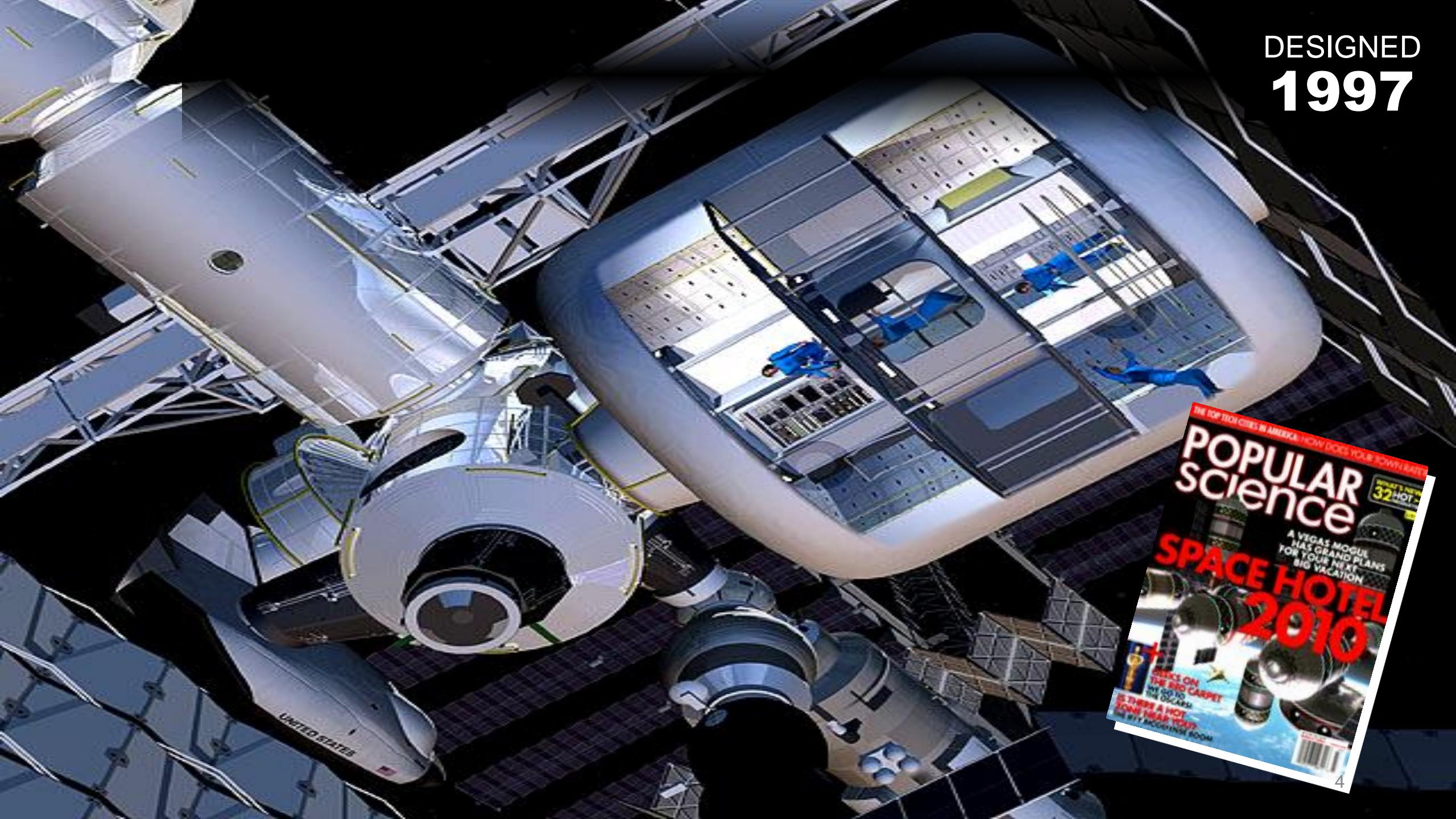
# TransHAB Inflatable Prototype Module *Space Architecture*



# NASA TransHab Concept

- TransHab was a light weight inflatable habitation module for space applications
- Original 1997 concept for light weight habitat module for human mission transit to Mars
- Proposed to the International Space Station (ISS) Program as a replacement for a Hab Module





DESIGNED  
**1997**

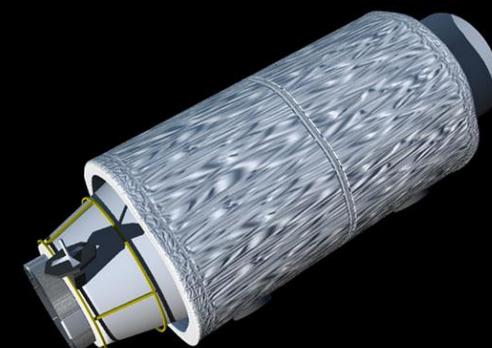




# Transportation Constraints



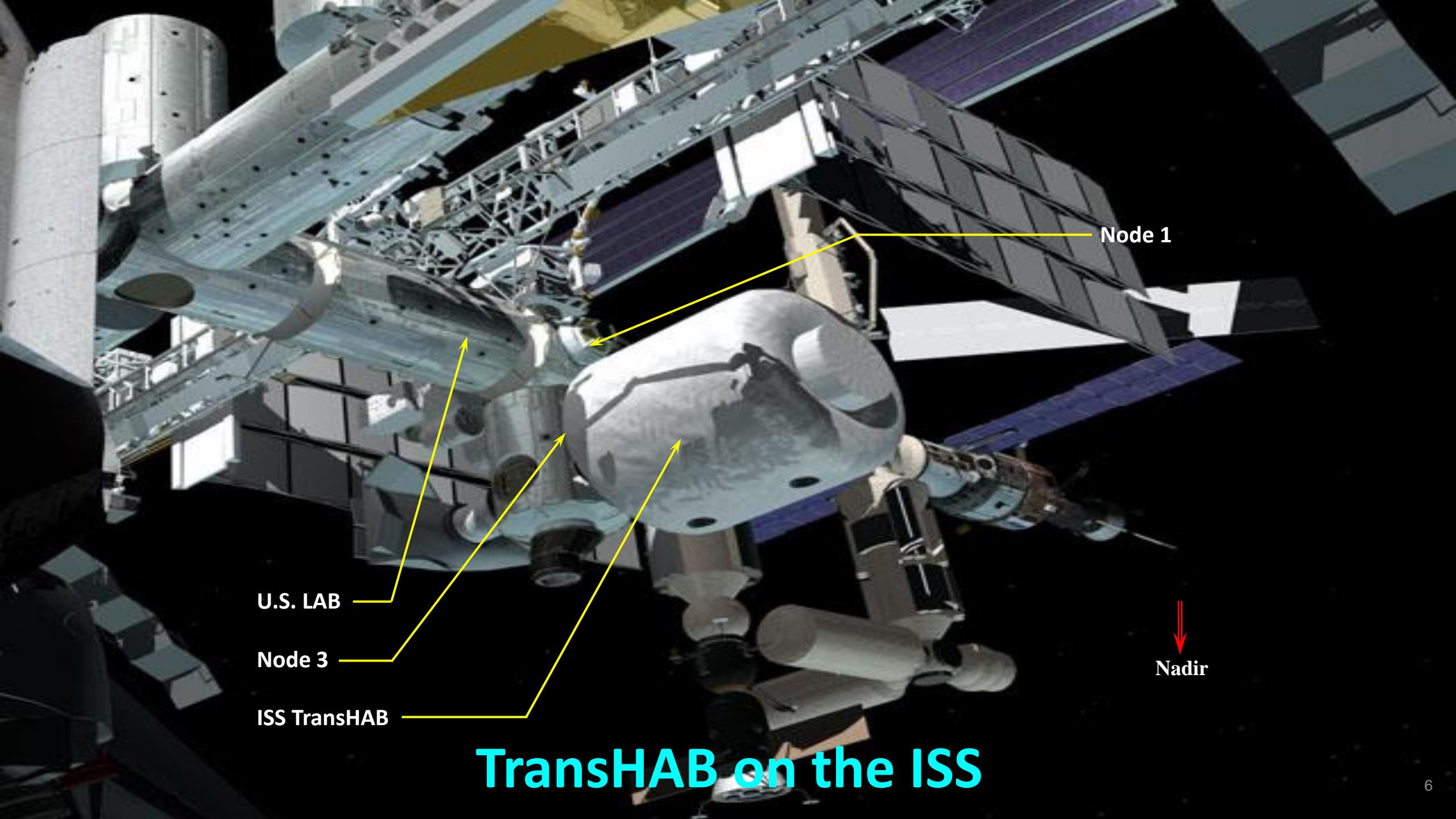
TransHab Launch Package



Robotic Arm Removal  
& Installation on ISS



Inflated TransHab



# *ISS TransHAB*



**Level 4:** Pressurized Tunnel

**Level 3:** Crew Health Care

**Level 2:** Crew Quarters & Mechanical Room

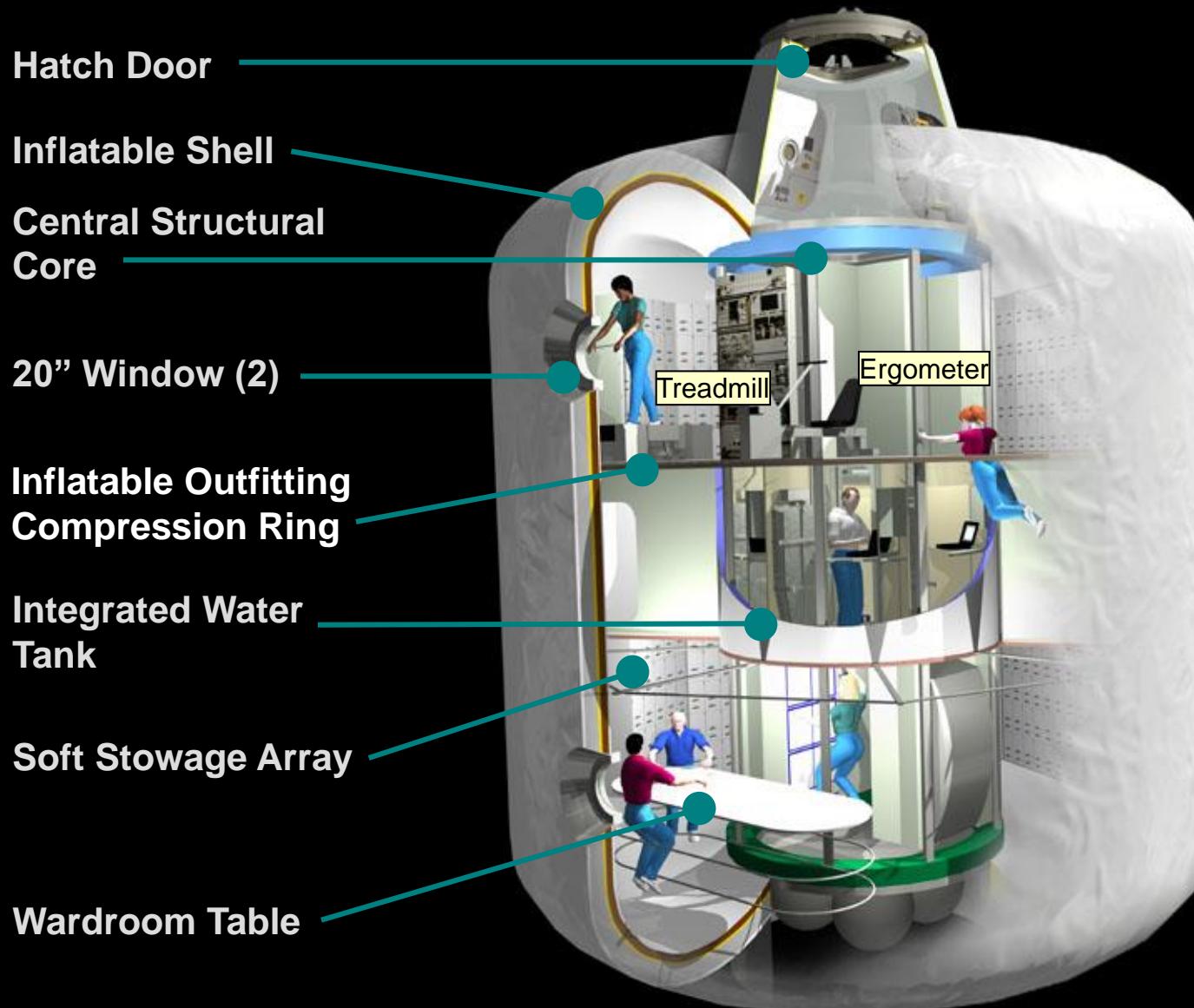
**Level 1:** Galley & Wardroom

## ISS TransHAB Functions

- Private Crew Quarters
- Galley & Dining
- Meeting area for entire ISS crew
- Health Care & Exercise
- Hygiene
- Stowage
- Crew Accommodations
- Environmental Control & Life Support System (ECLSS)
- Communications
- Command, Control & Data Handling
- Protection during Solar Particle Events



# ISS TransHab Architecture



**Level 4: Pressurized Tunnel**

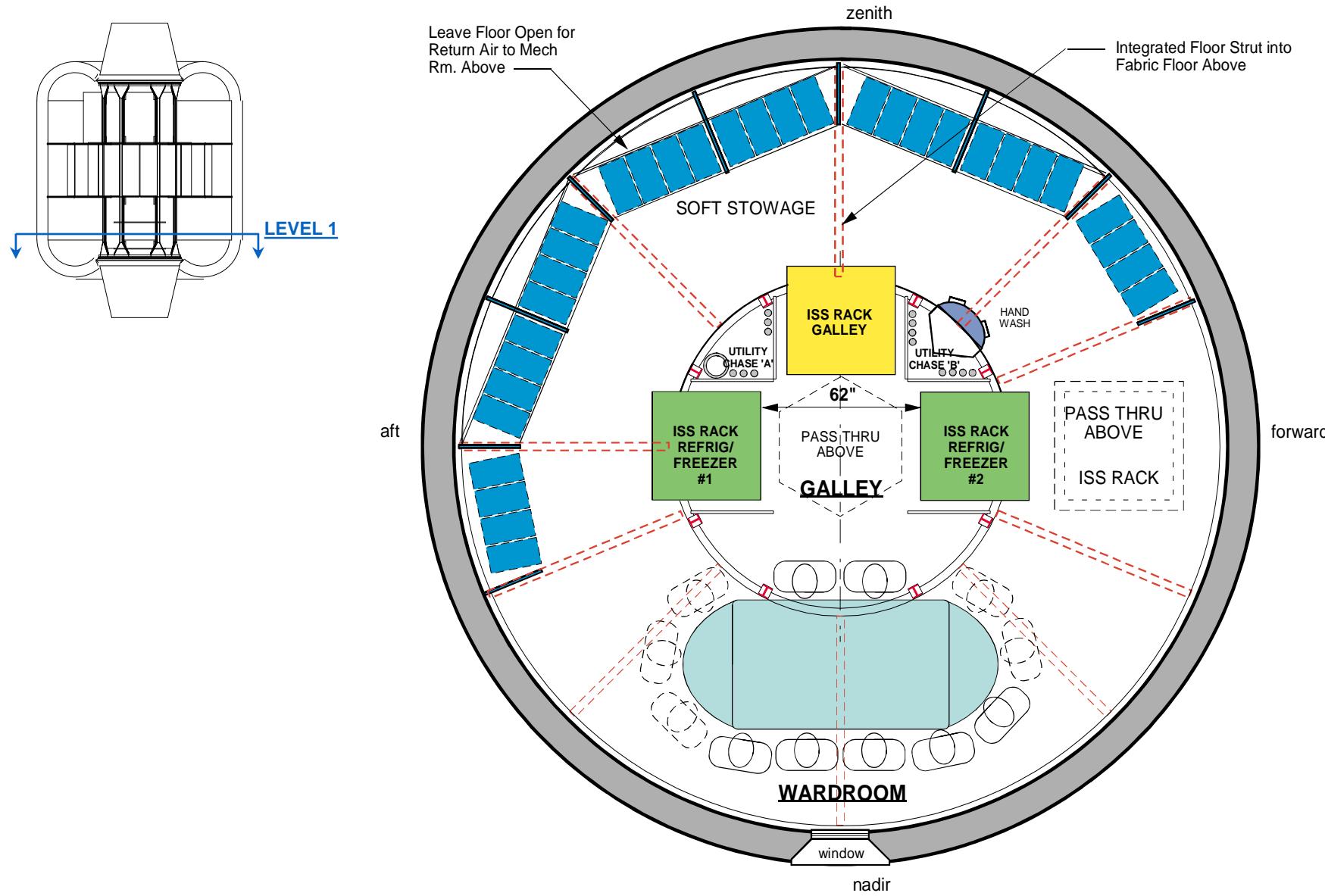
**Level 3: Crew Health Care**

**Level 2: Crew Quarters and Mechanical Room**

**Level 1: Galley and Wardroom**

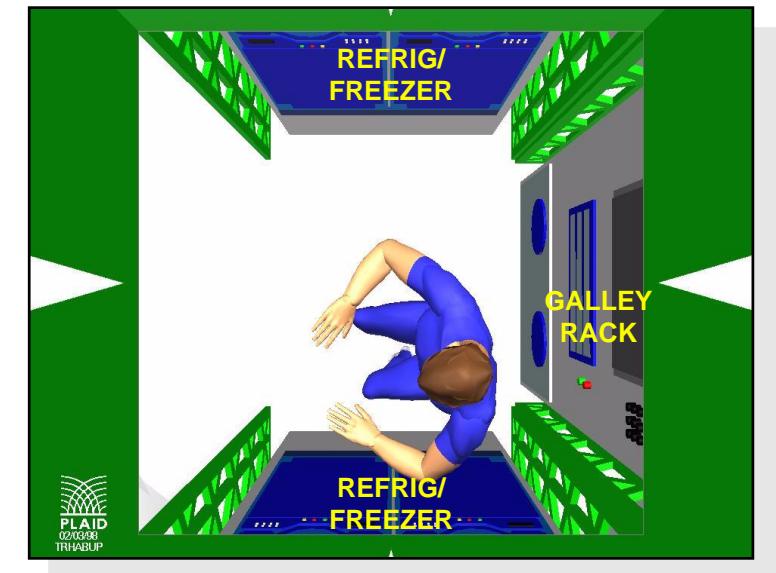
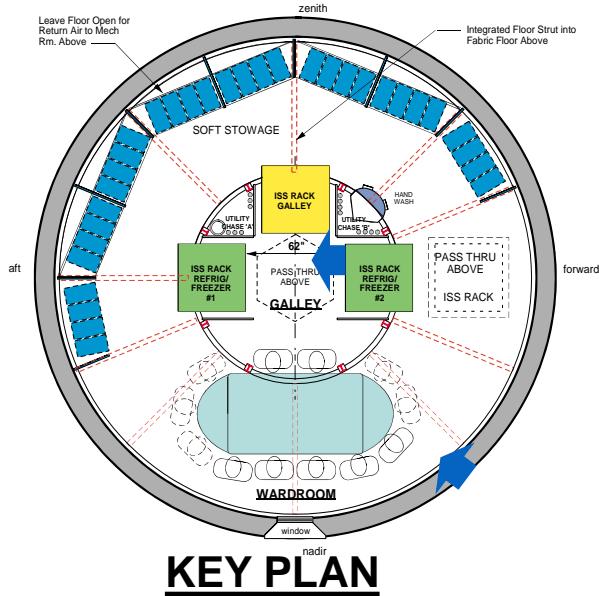


# Level 1



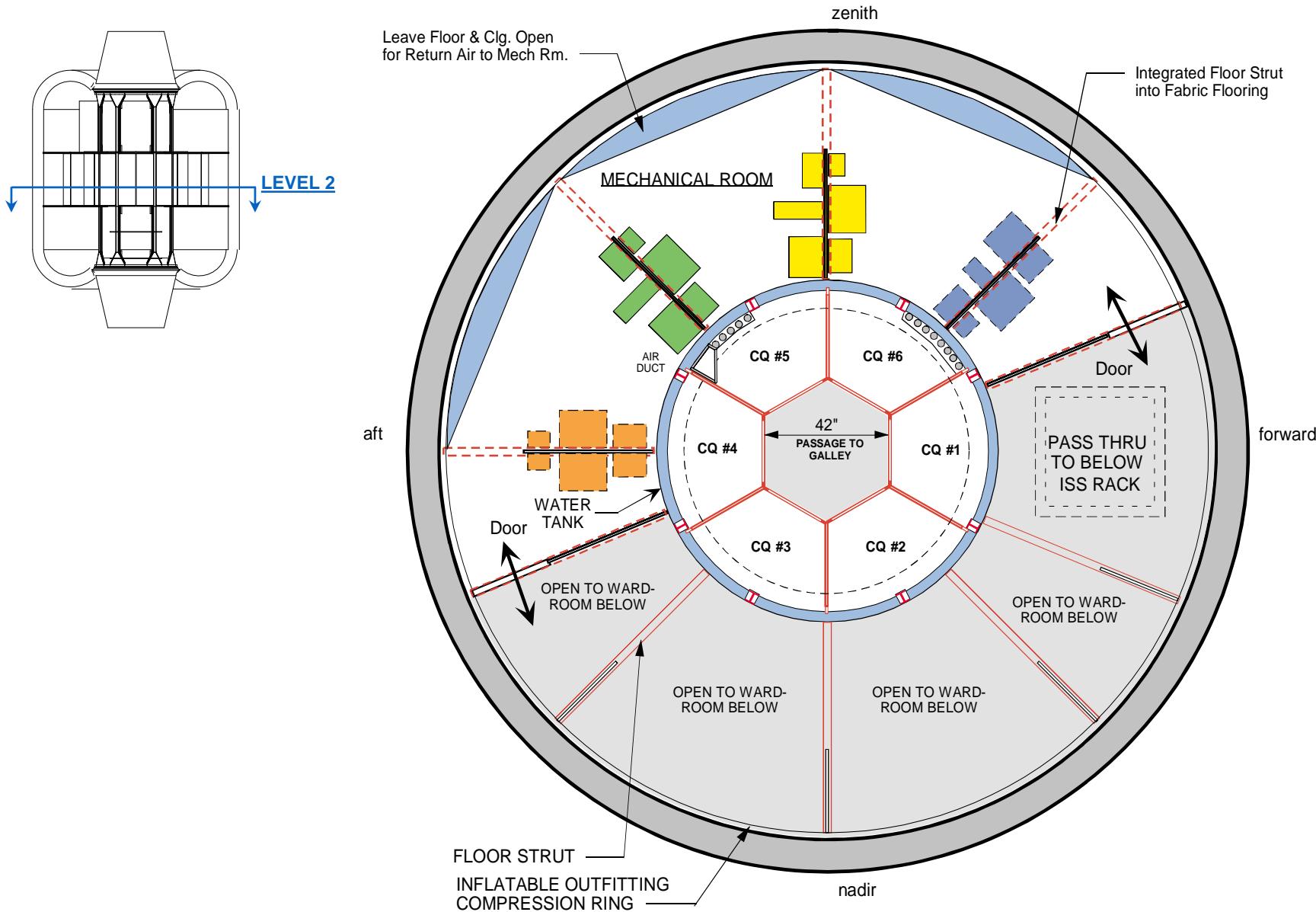


# Galley / Wardroom Area



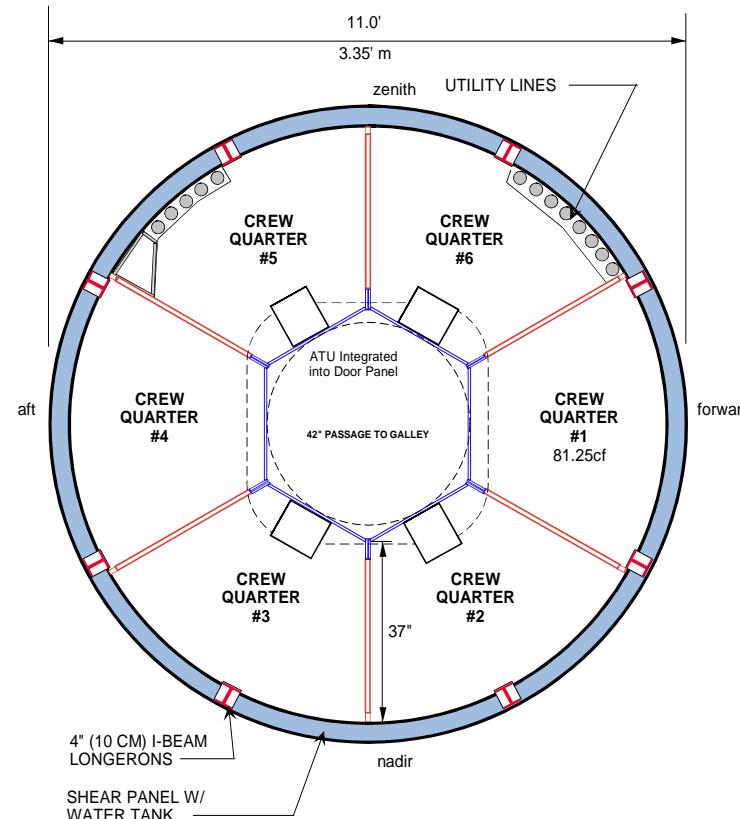
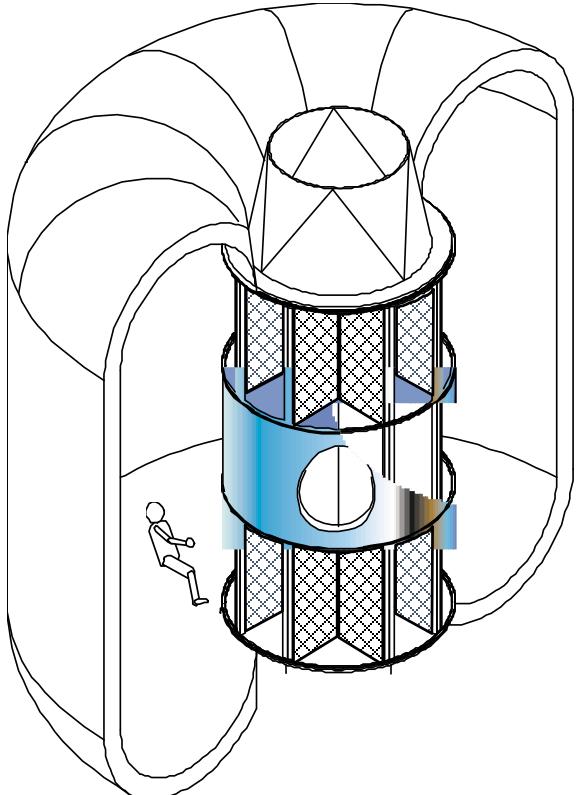


# Level 2





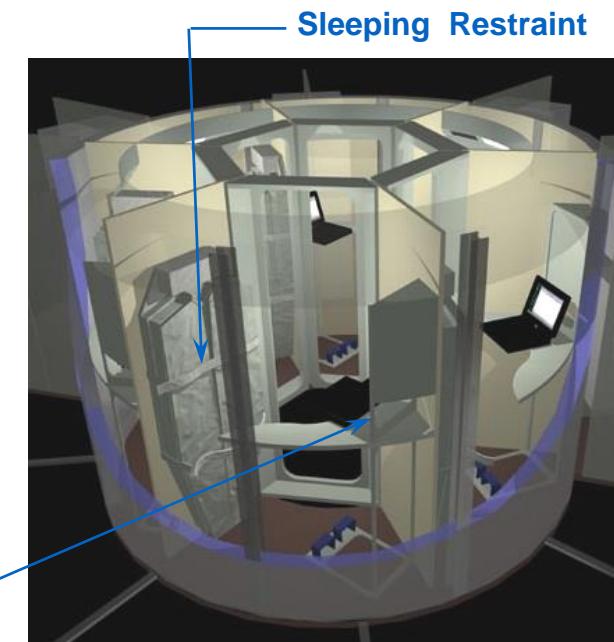
# Private Crew Quarters



Crew Personal Unit: Entertainment & Work  
Substation Unit: Light Weight Frame and Fabric That Packages Into a Box.

Provides: (design for 0g)

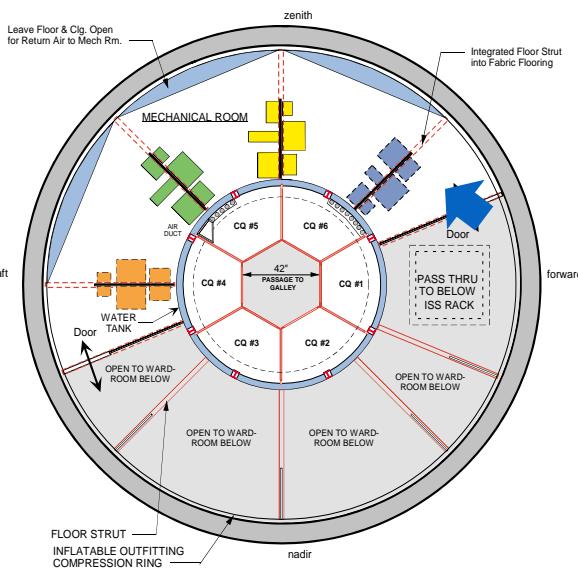
- 6 Crew Quarters
- **81.25 ft<sup>3</sup> of Volume:**
  - 27% Larger than ISS Rack
  - ISS Rack Crew Quarter = 64 ft<sup>3</sup> +/- (without bump out)
- Private Space
- Quiet Space
- Sleep Area
- Personal Stowage Area
- Radiation Protection



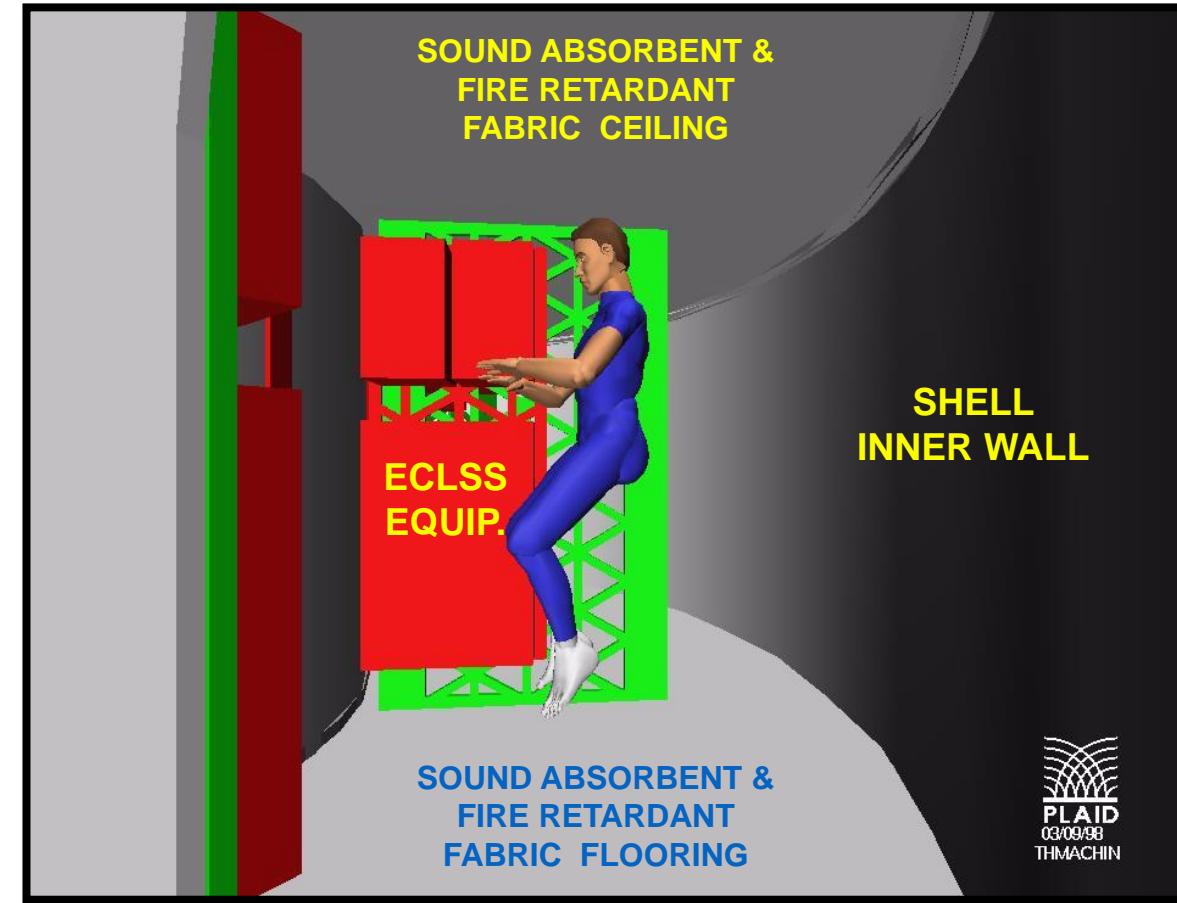
Typical Crew Quarter



# ECLSS Equipment Area



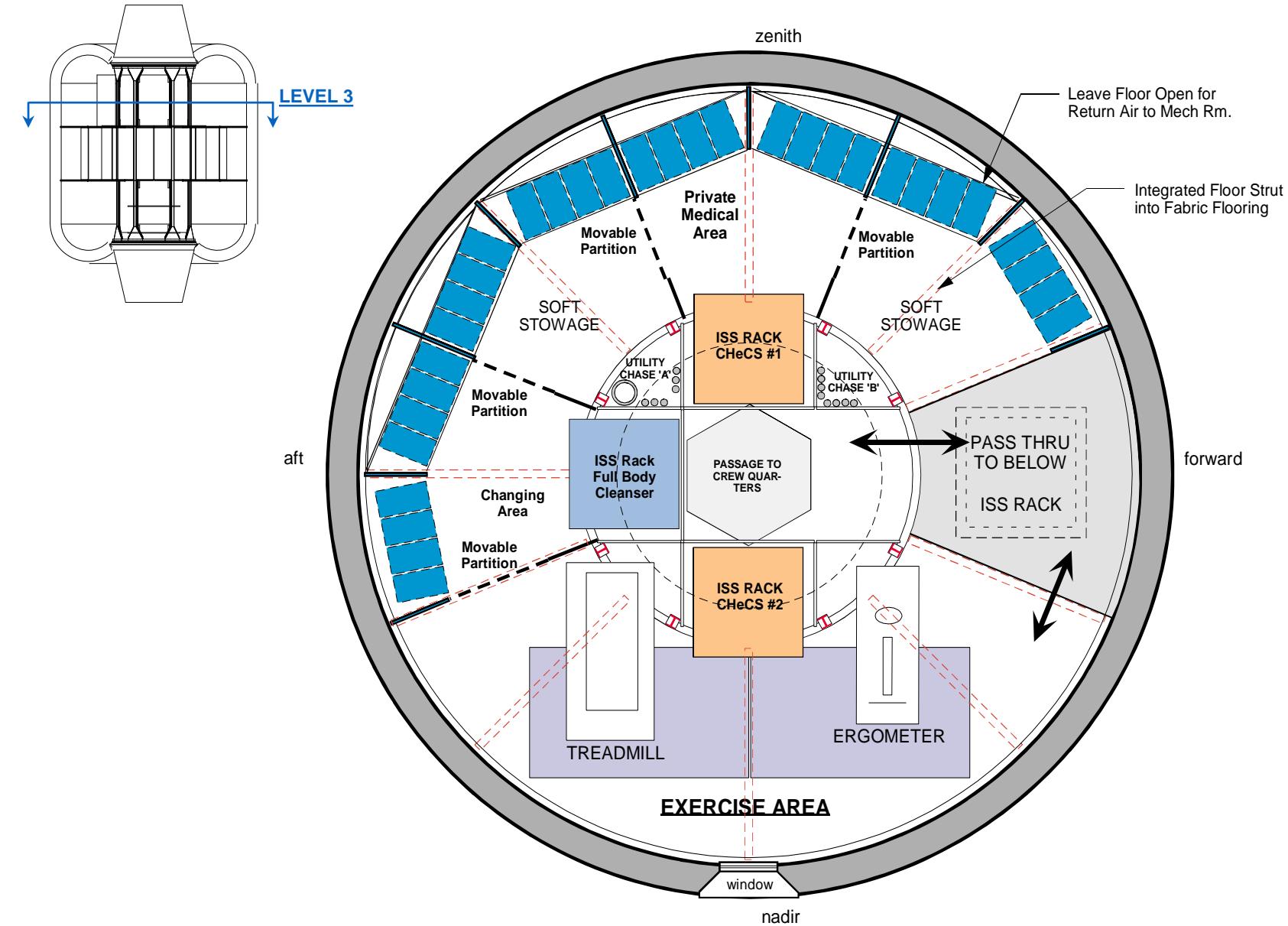
**KEY PLAN**



**MECHANICAL ROOM**

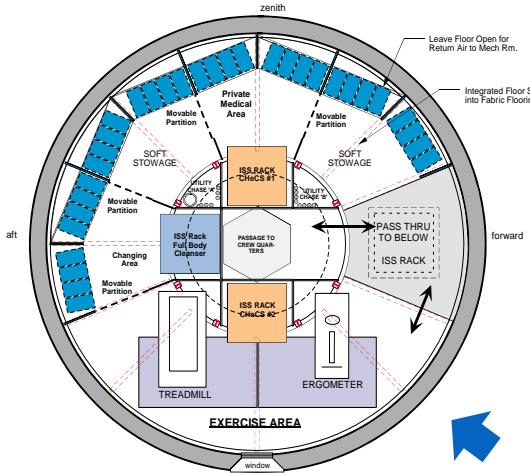


# Level 3





# Crew Health Care Area



**KEY PLAN**

**EXERCISE AREA**



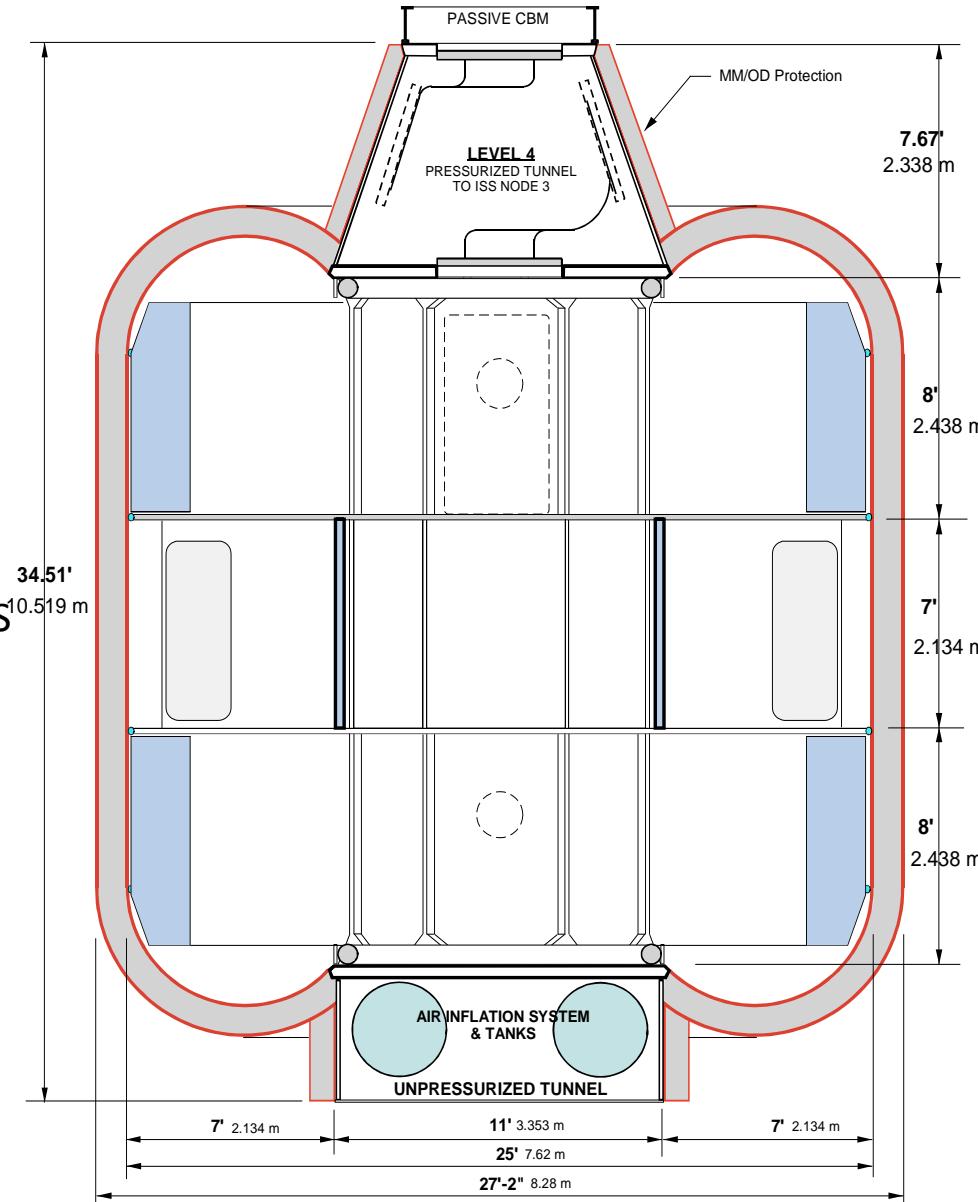


# TransHab Specs

- Overall Length = 10.5 m
- OA Deployed Width = ~8.3 m
- Internal Diameter = 7.6 m
- Packaged volume = 342 m<sup>3</sup>
- Deployed volume = ~161 m<sup>3</sup>
- ConOps
  - Packaged around Hard Core
  - During Launch-goes to vacuum except Tunnel
  - Removed from Cargo Bay & Berthed to ISS
  - Slowly inflated with warmed air. Equalize & stabilize.
  - Crew unpack and assembly.
  - Checkout and verify operational

SHELL Vol = 11631 ft<sup>3</sup> (329.37 m<sup>3</sup>)  
TUNNEL Vol = 446 ft<sup>3</sup> (12.63 m<sup>3</sup>)  
Total Vol = 12077 ft<sup>3</sup> (342.0 m<sup>3</sup>)

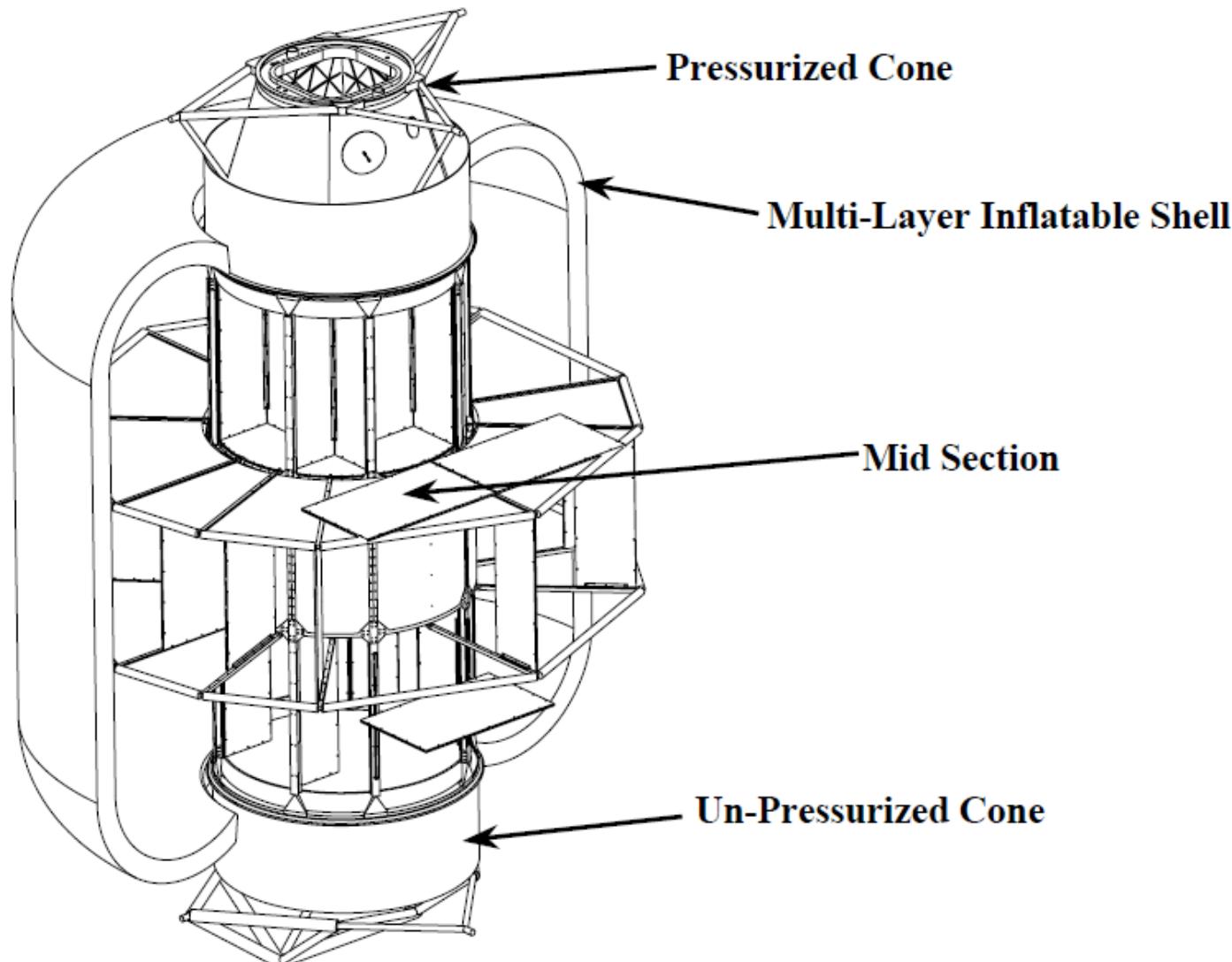
2.74x larger an ISS Lab/Hab Module  
Vol. (4414 ft<sup>3</sup>, or 125 m<sup>3</sup>)





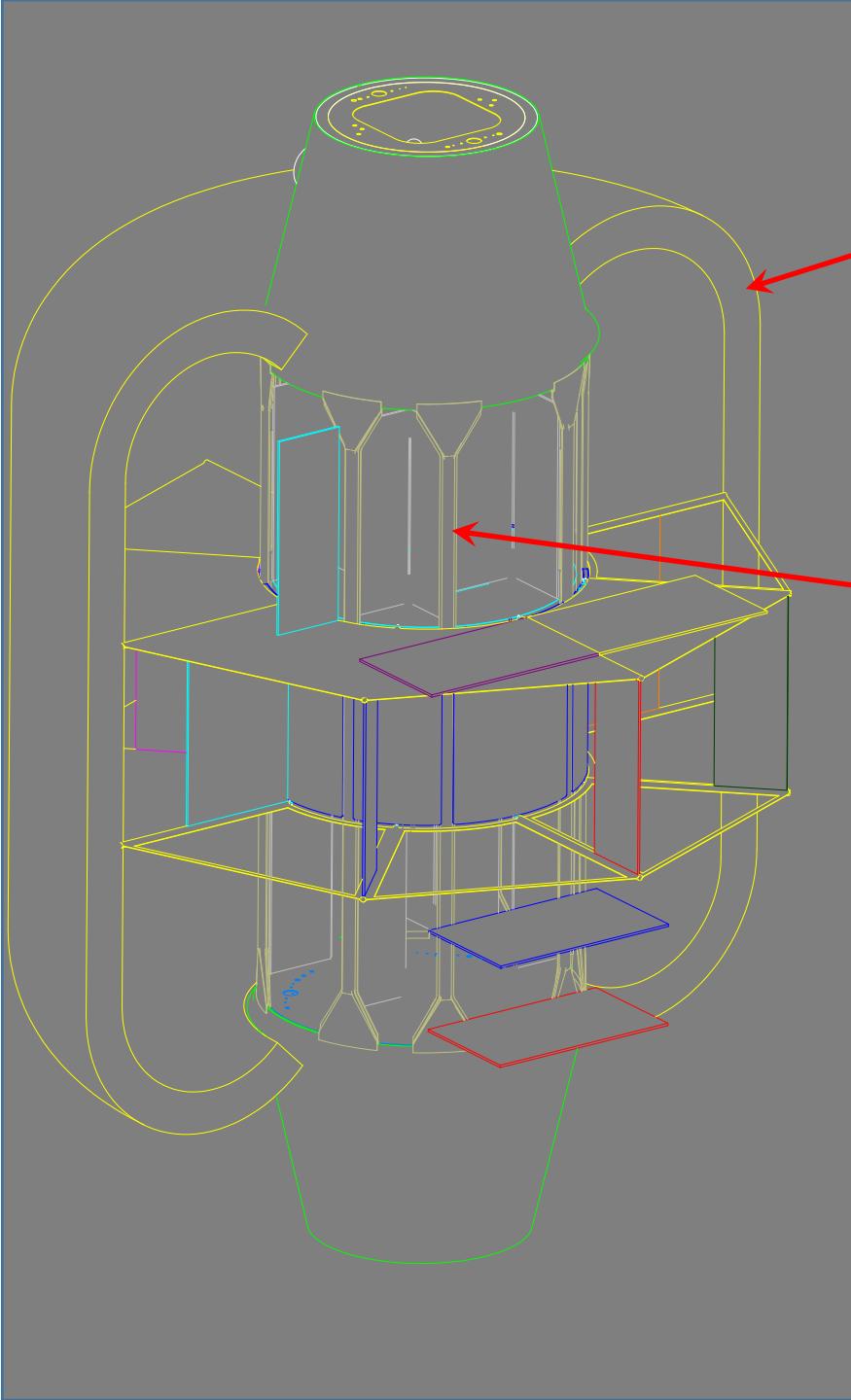
# Structural Overview

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# General Structural Configuration

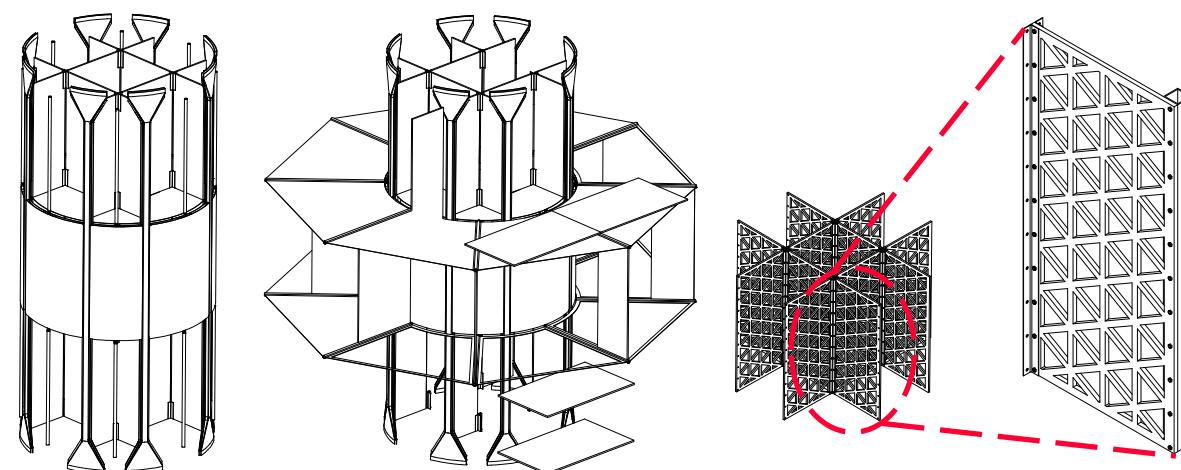


## Multi-Layer Inflatable Shell

- Multi-Layer Insulation Blankets
- Micrometeoroid / orbital debris Protection
- Optimized Restraint Layer
- Redundant Bladder With Protective Layer

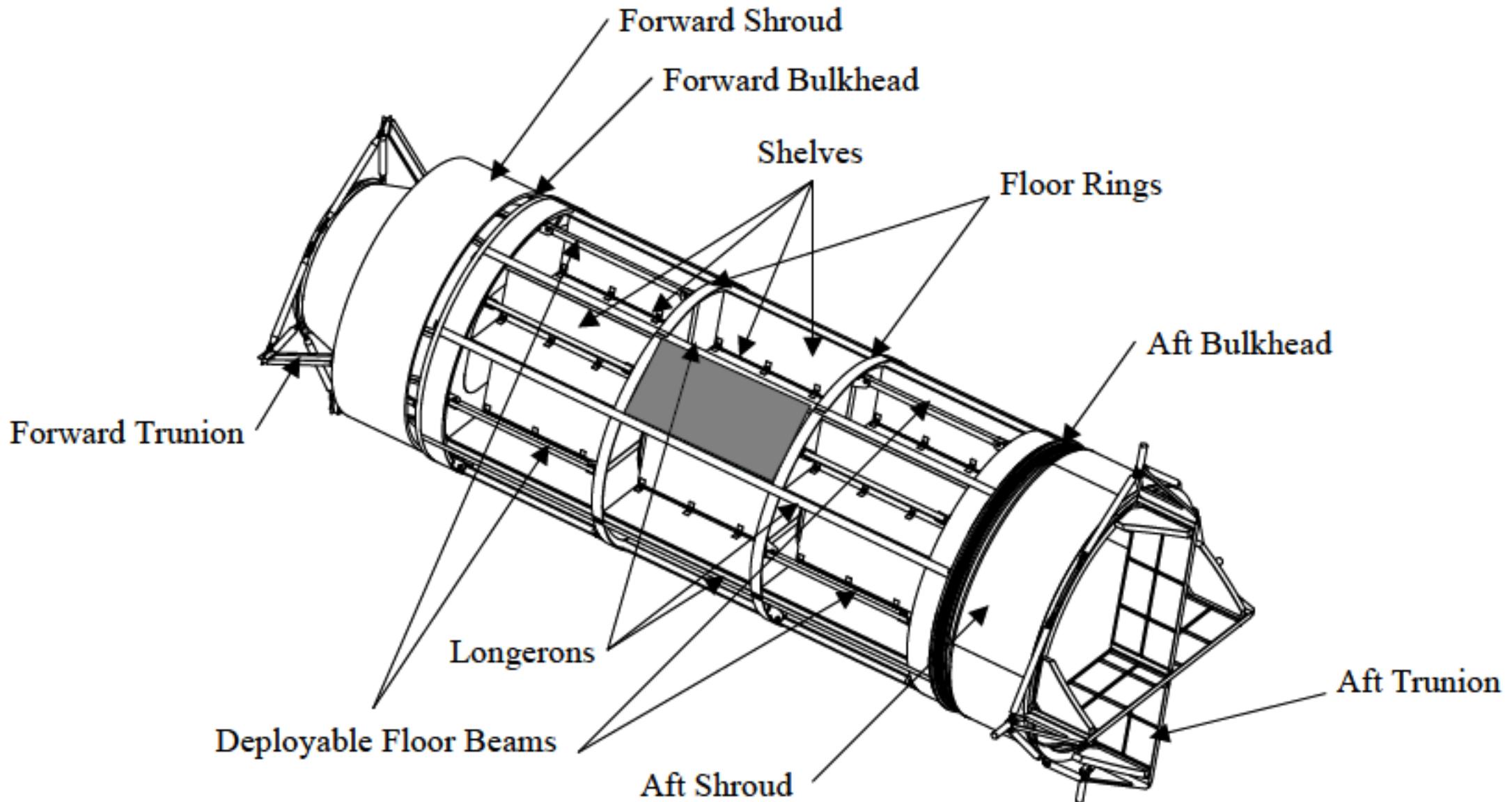
## Central Structural Core

- 2 Tunnels
- Composite Core With Integral Water Tank
- Repositionable Composite Isogrid shelves
- Floor Struts With Fabric Flooring



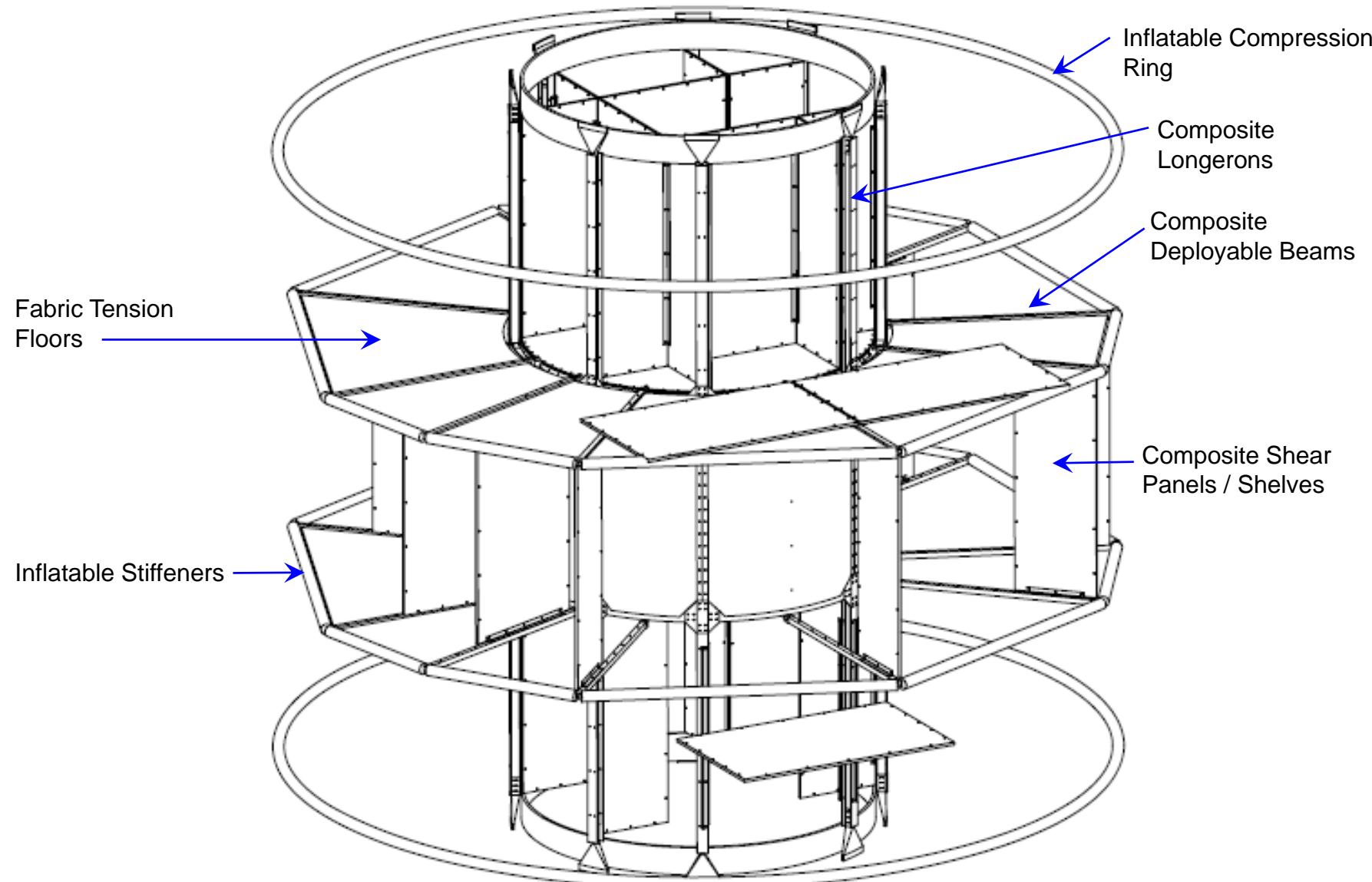


# Structural Hard Core



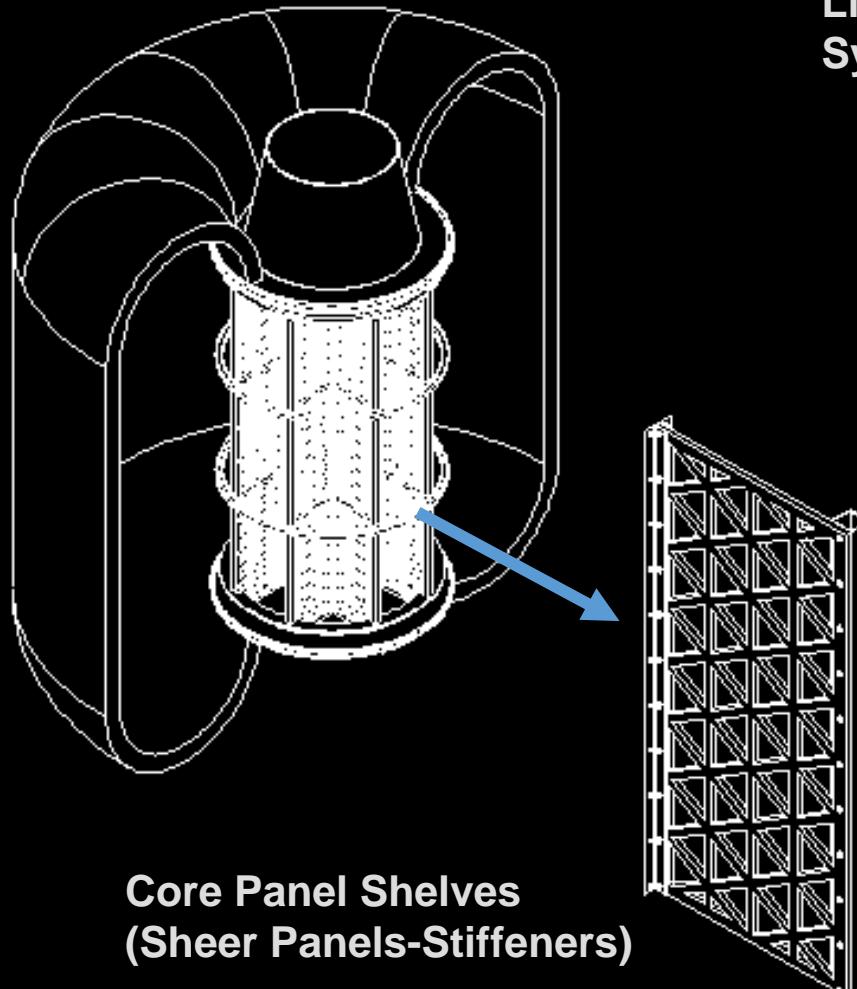


# Deployed Internal Structure Overview





# *Subsystems Packaged in Core*



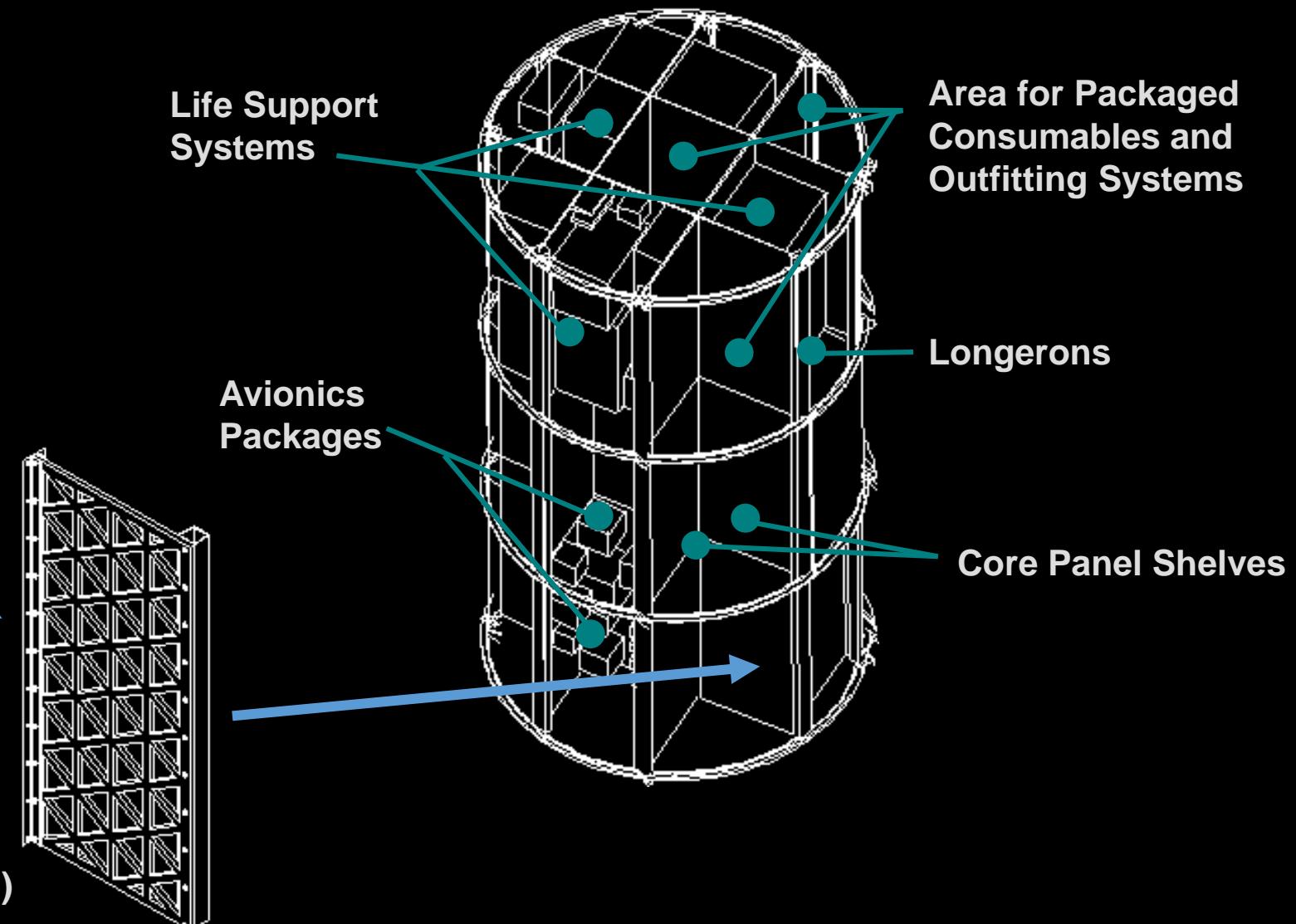
Life Support  
Systems

Avionics  
Packages

Area for Packaged  
Consumables and  
Outfitting Systems

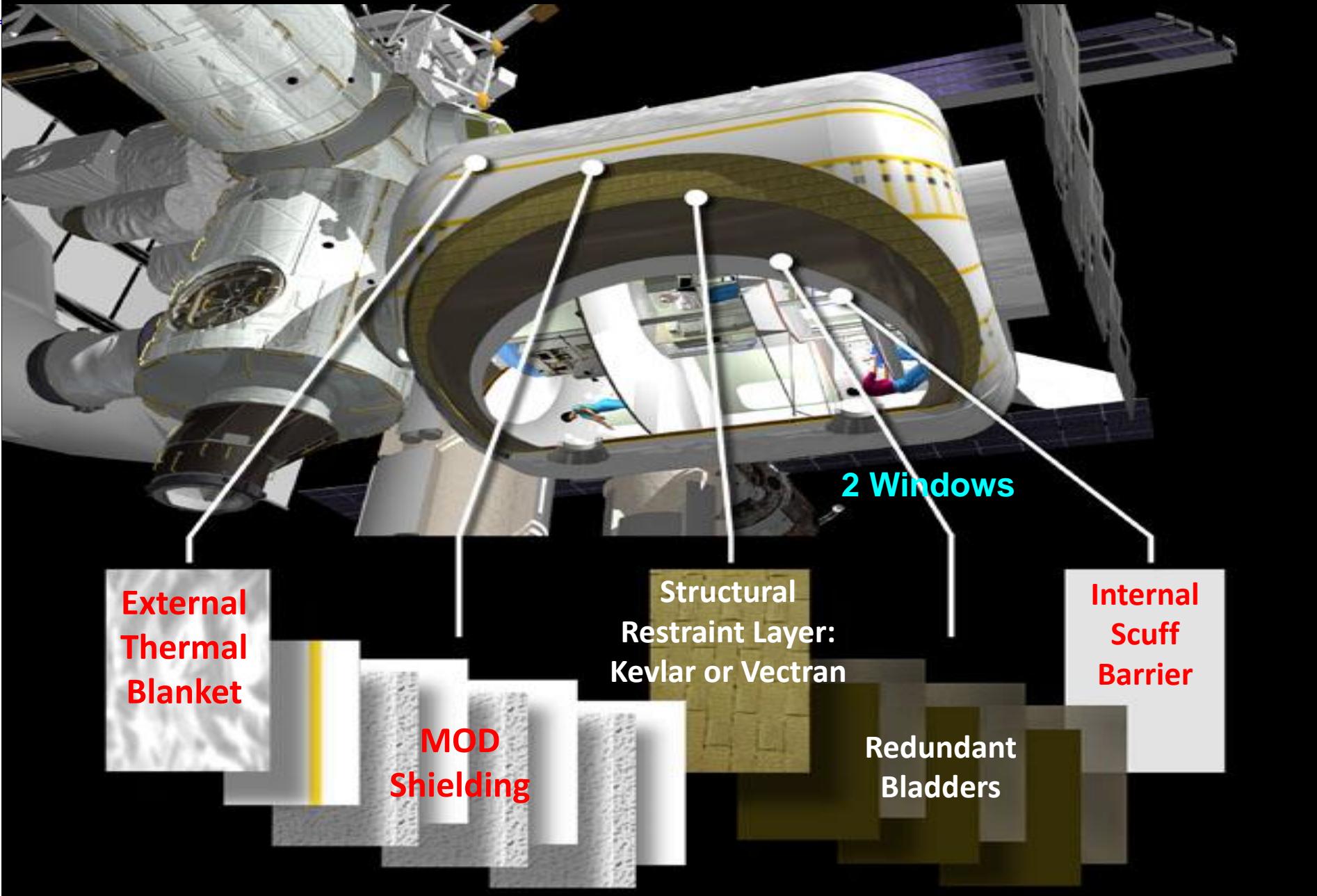
Longerons

Core Panel Shelves



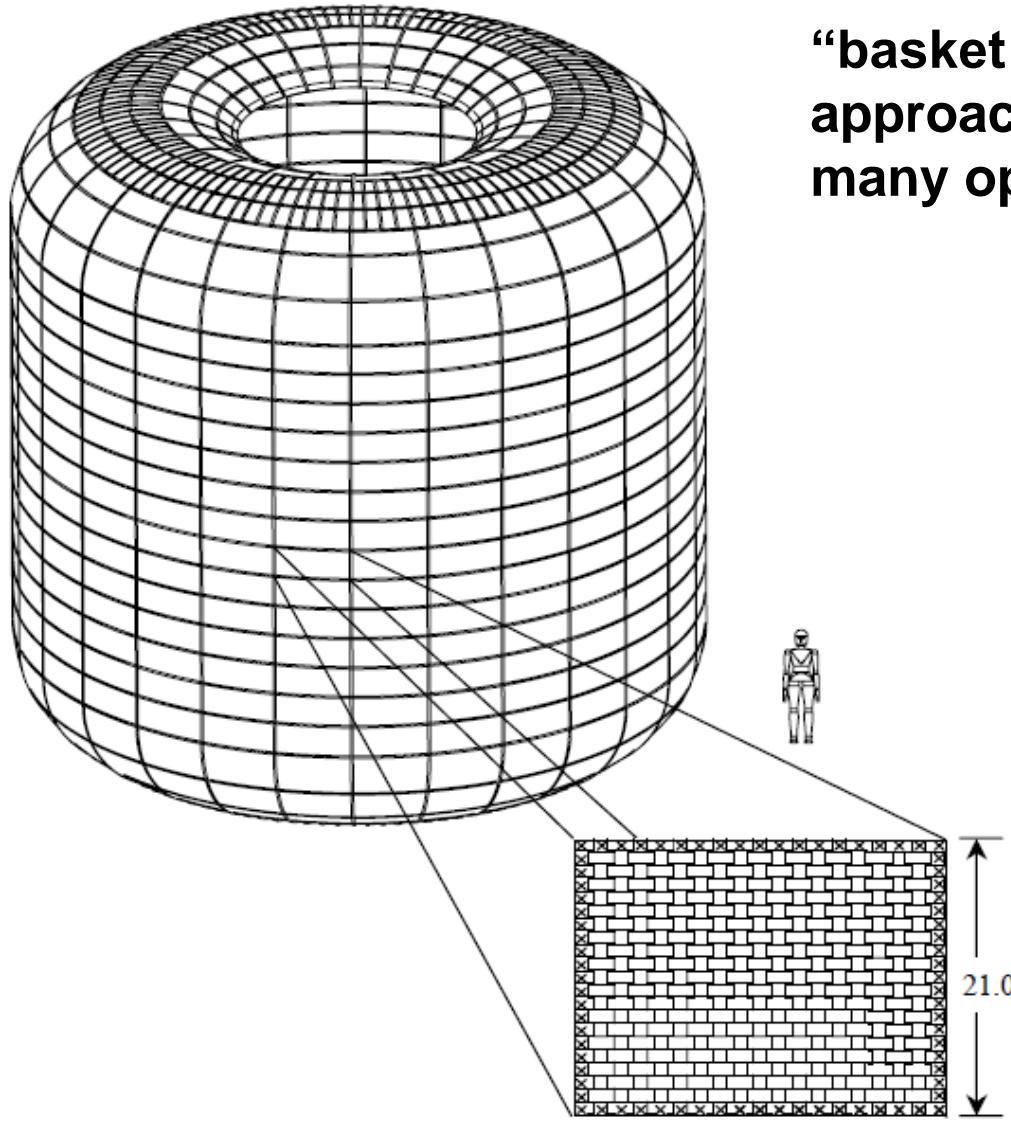


# Multi-Functional Layered Inflatable Pressure Shell





# Inflatable Restraint Layer

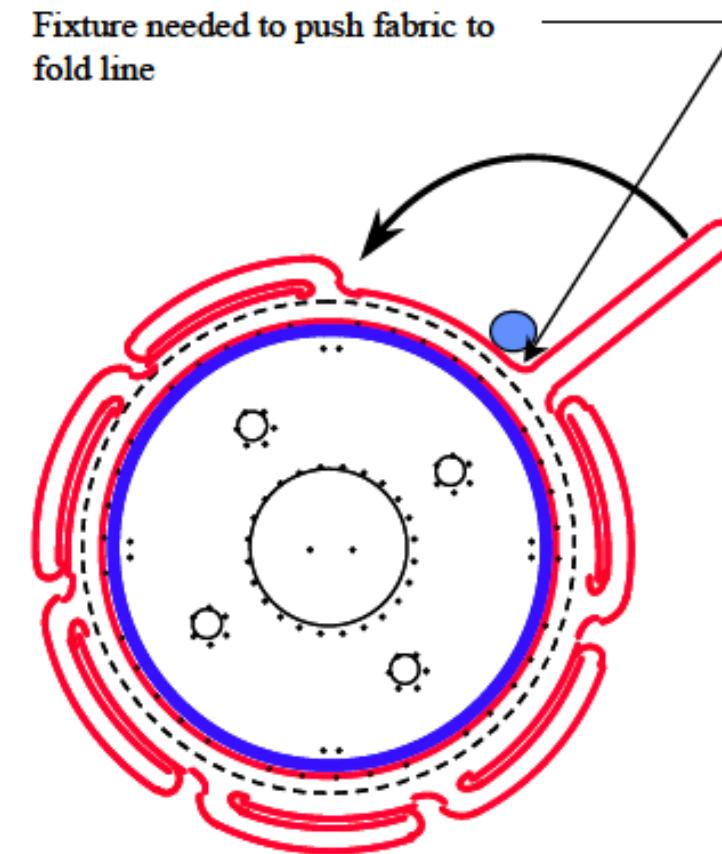
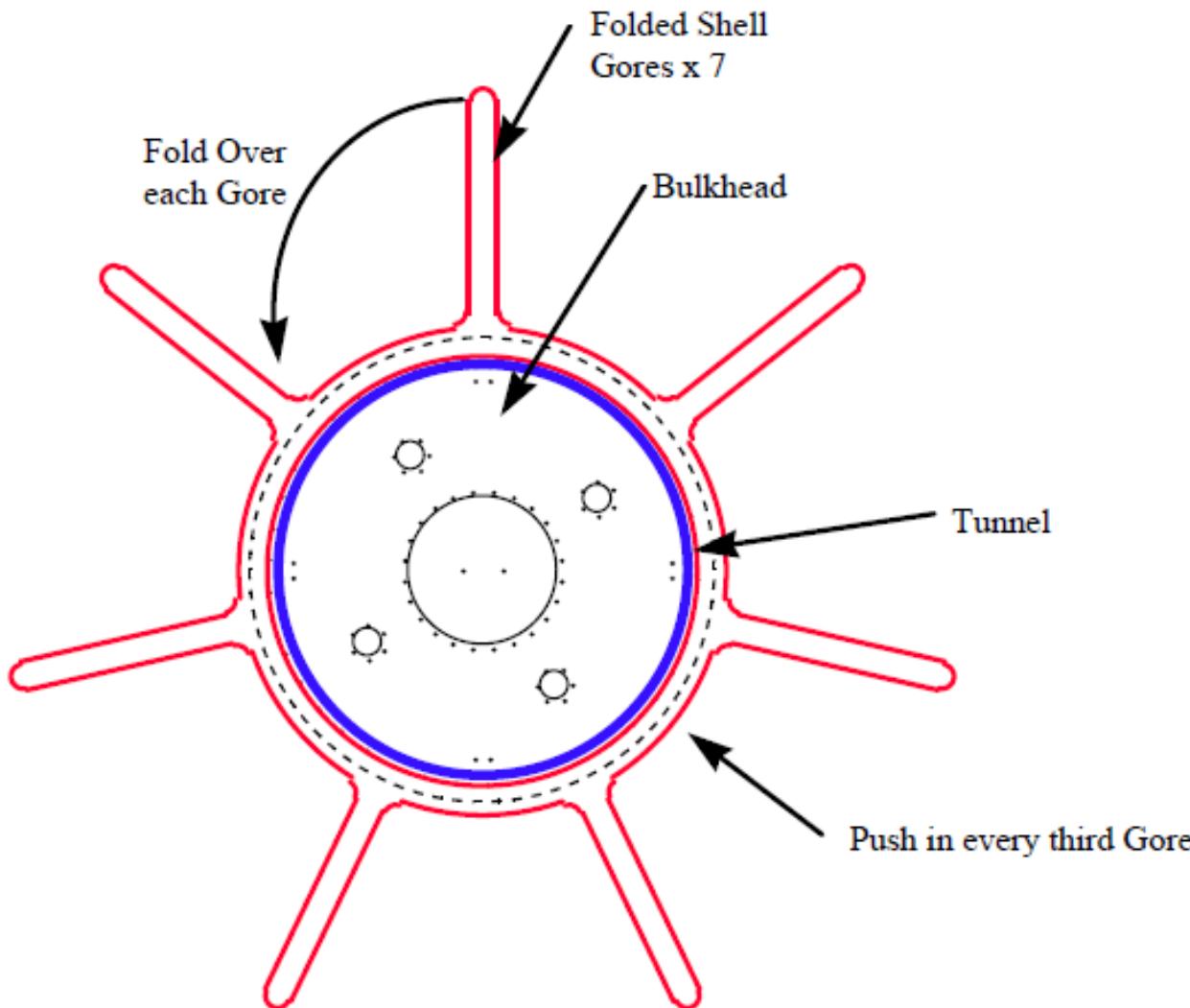


“basket weave” manufacturing approach. Manually labor intensive and many opportunities for human error.





# Packaging & Folding





# Notional Shell Structural Interface

Due to export control and patent license agreements NASA can not share the details.

## Inflatable Shell Assembly and Integration

- Load Frame for restraint layer straps interface, Clevis Pins
- Bladder Attach Ring
- Bladders (redundancy) Bonded to Ring
- Bladder Peel Guard Ring
- Scuff Layer Interface



# Notional Window Detail

Due to export control and patent license agreements NASA can not share the details.

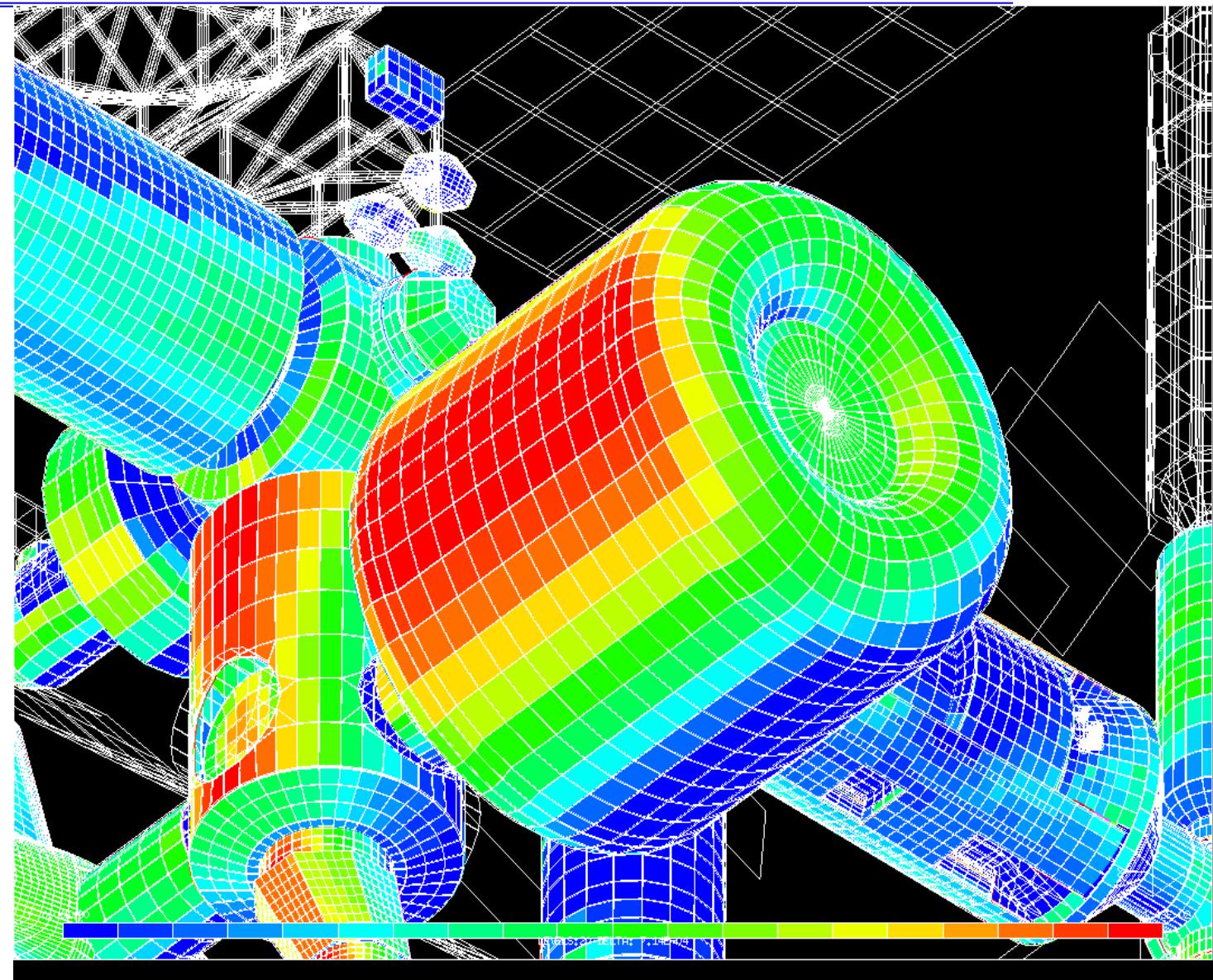
## Window Assembly and Integration

- Bladder Ring
- Load Frame for restraint layer straps interface
- Exterior cover
- Interior cover
- Scratch pane
- Pressure panes
- MMOD debris pane



# Goal 1: MMOD Test

- Requirement: HAB shall have a minimum of 0.9820 Probability of No Penetration (PNP)
- Designed and Build MMOD Shield
- Made test shots
- Shot after Shot
- Current shell configuration tested projectiles up to 1.7 cm diameter
- Due to the large size of TransHab, the Shielding required to meet the PNP is larger than the standard modules.

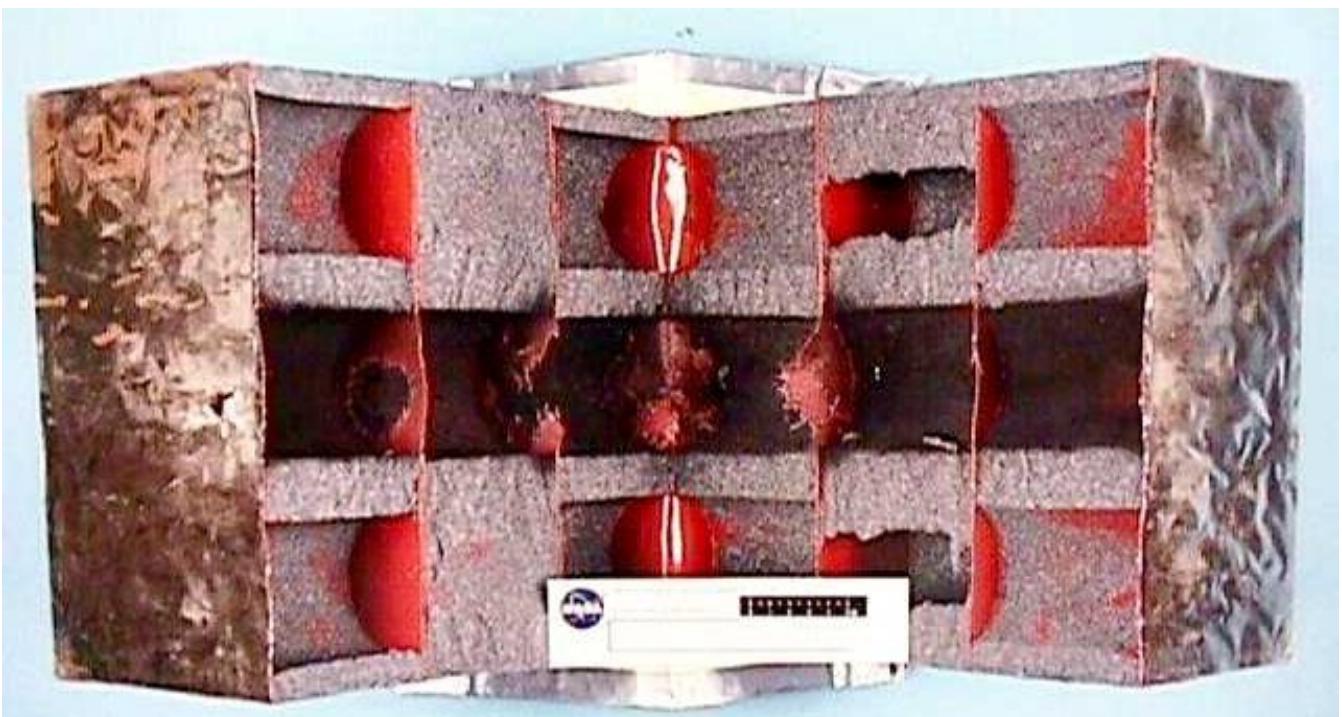
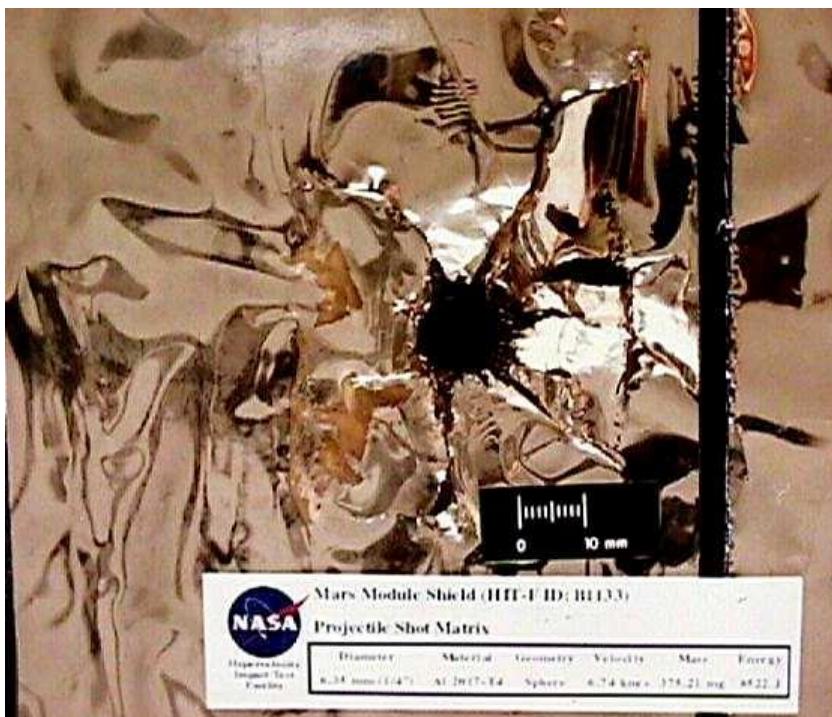




# MMOD Testing



Scientific American  
Frontiers TV: Alan Alda





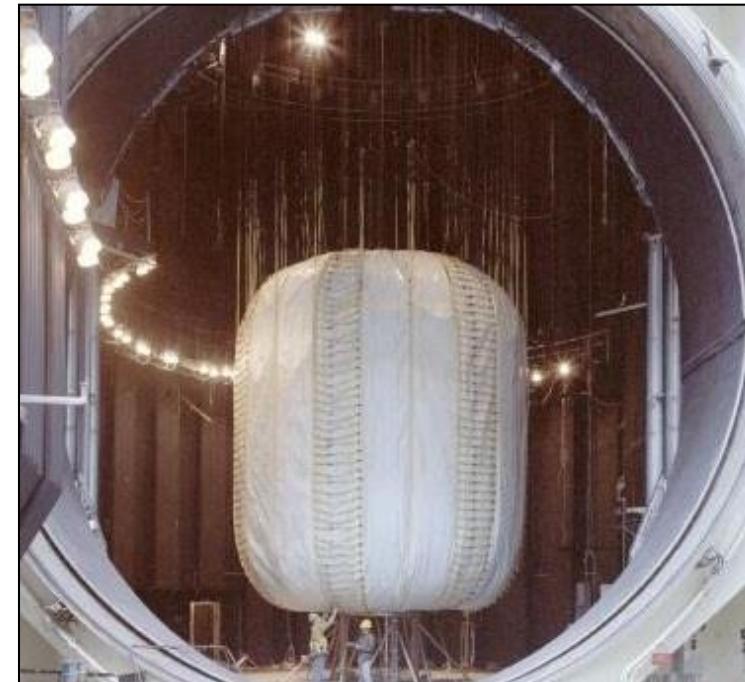
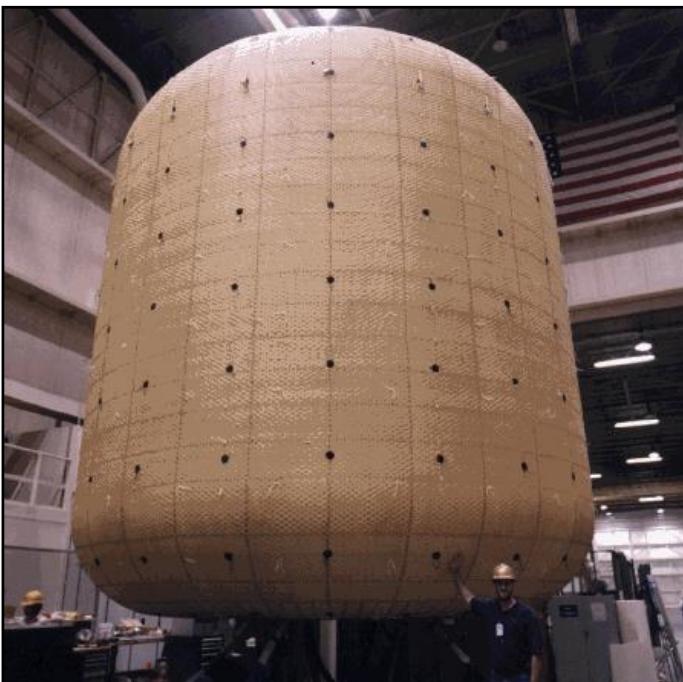
# Full-Scale Testing



Shell Dev. Unit-1 (30psid )



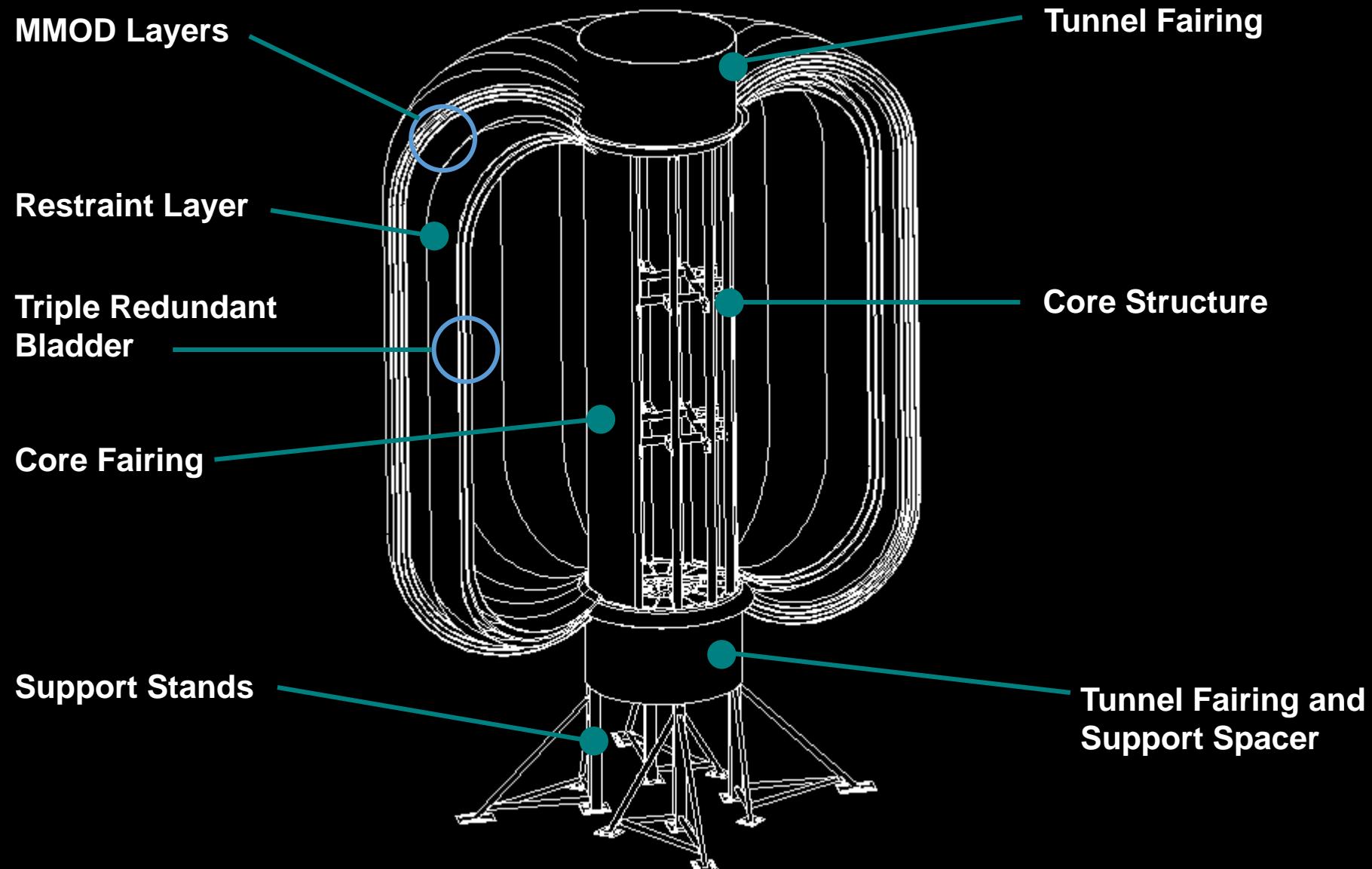
Shell Dev. Unit-2 (60psid )



Shell Dev. Unit-3 Full-scale Deployment in a Vacuum Environment



# *Full Scale Development Unit*





# *TransHab Full Scale Shell Development Unit (SDU-3)*

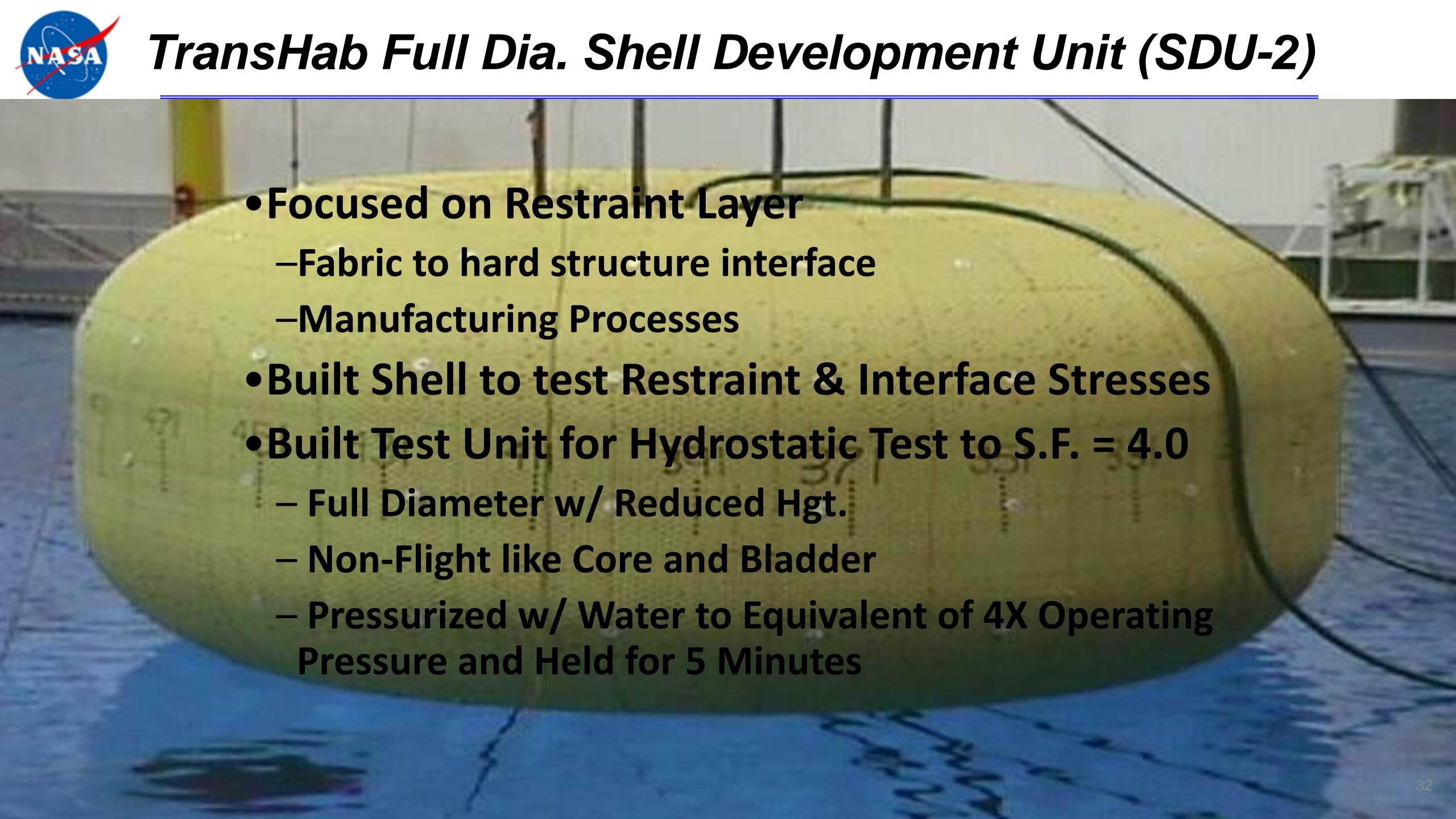


**First Inflation: November 17, 1998**





# *TransHab Full Dia. Shell Development Unit (SDU-2)*

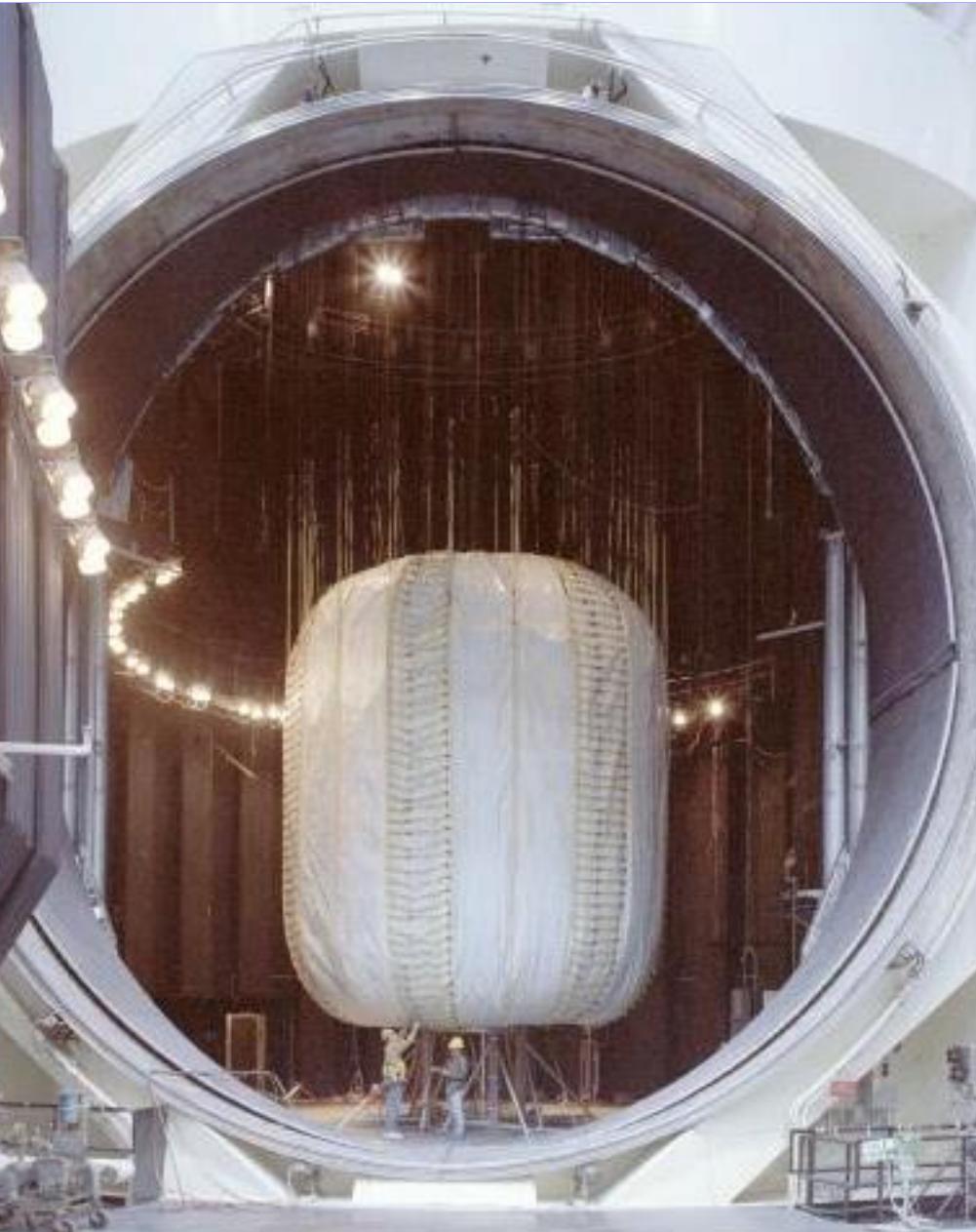
A large, yellowish-green, dome-shaped TransHab shell is being tested in a hydrostatic test facility. The shell is supported by a network of black cables and stands on a blue-painted metal platform. In the background, a white building with a green roof is visible.

- **Focused on Restraint Layer**
  - Fabric to hard structure interface
  - Manufacturing Processes
- **Built Shell to test Restraint & Interface Stresses**
- **Built Test Unit for Hydrostatic Test to S.F. = 4.0**
  - Full Diameter w/ Reduced Hgt.
  - Non-Flight like Core and Bladder
  - Pressurized w/ Water to Equivalent of 4X Operating Pressure and Held for 5 Minutes



## ***Full Scale Shell Development Unit (SDU-3) Vacuum Test***

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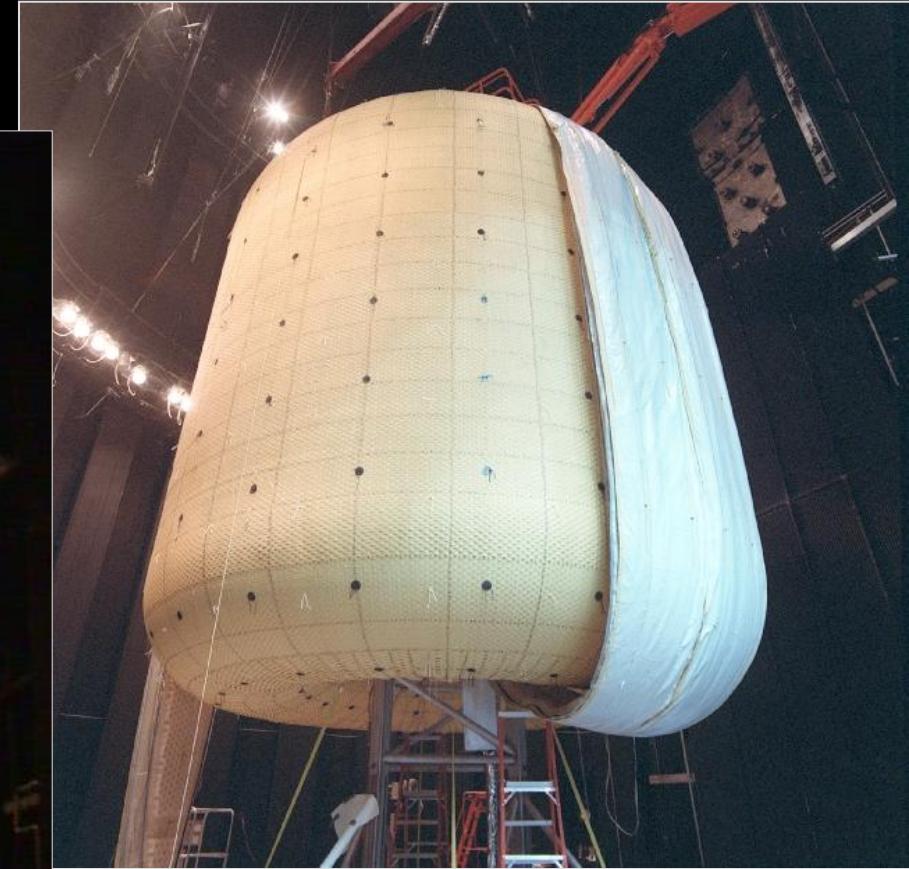
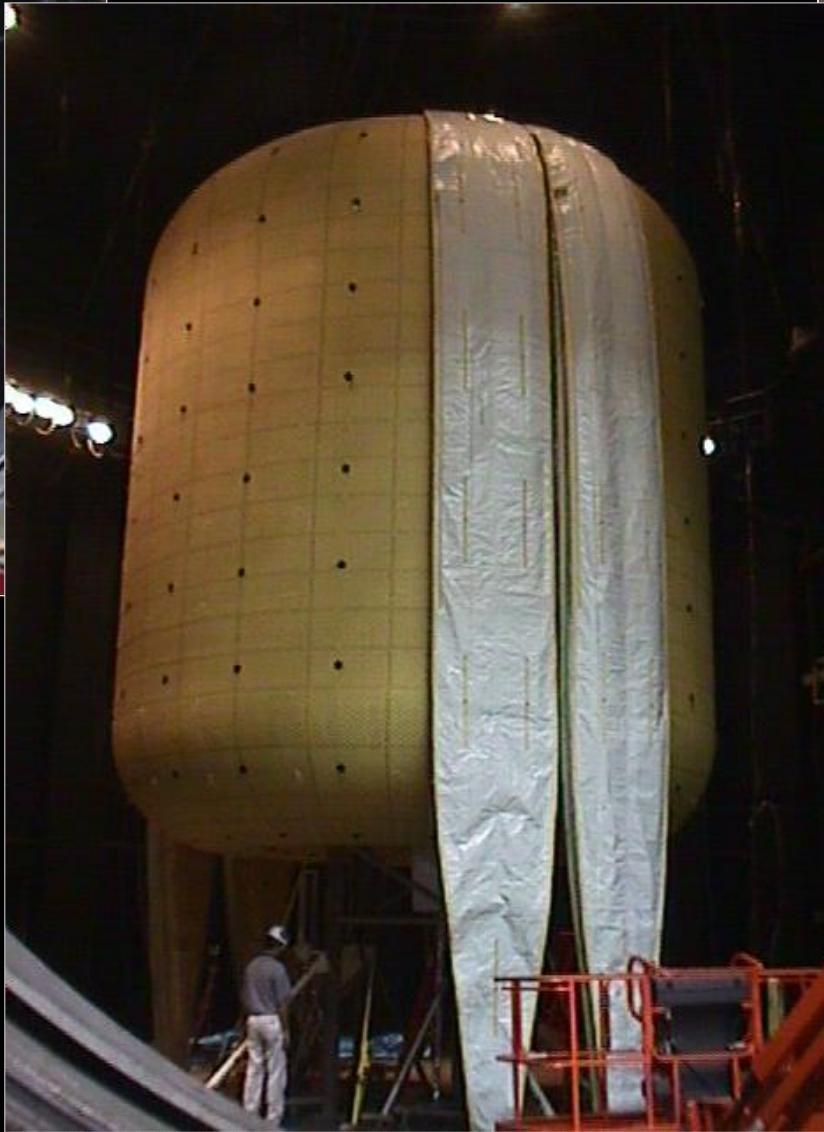


### **Demonstrated:**

- **Folding of Shell**
- **Packaging for Shuttle Payload Bay**
- **Operation in a Vacuum**
- **Deployment of Shell**
- **Inflation of Module**

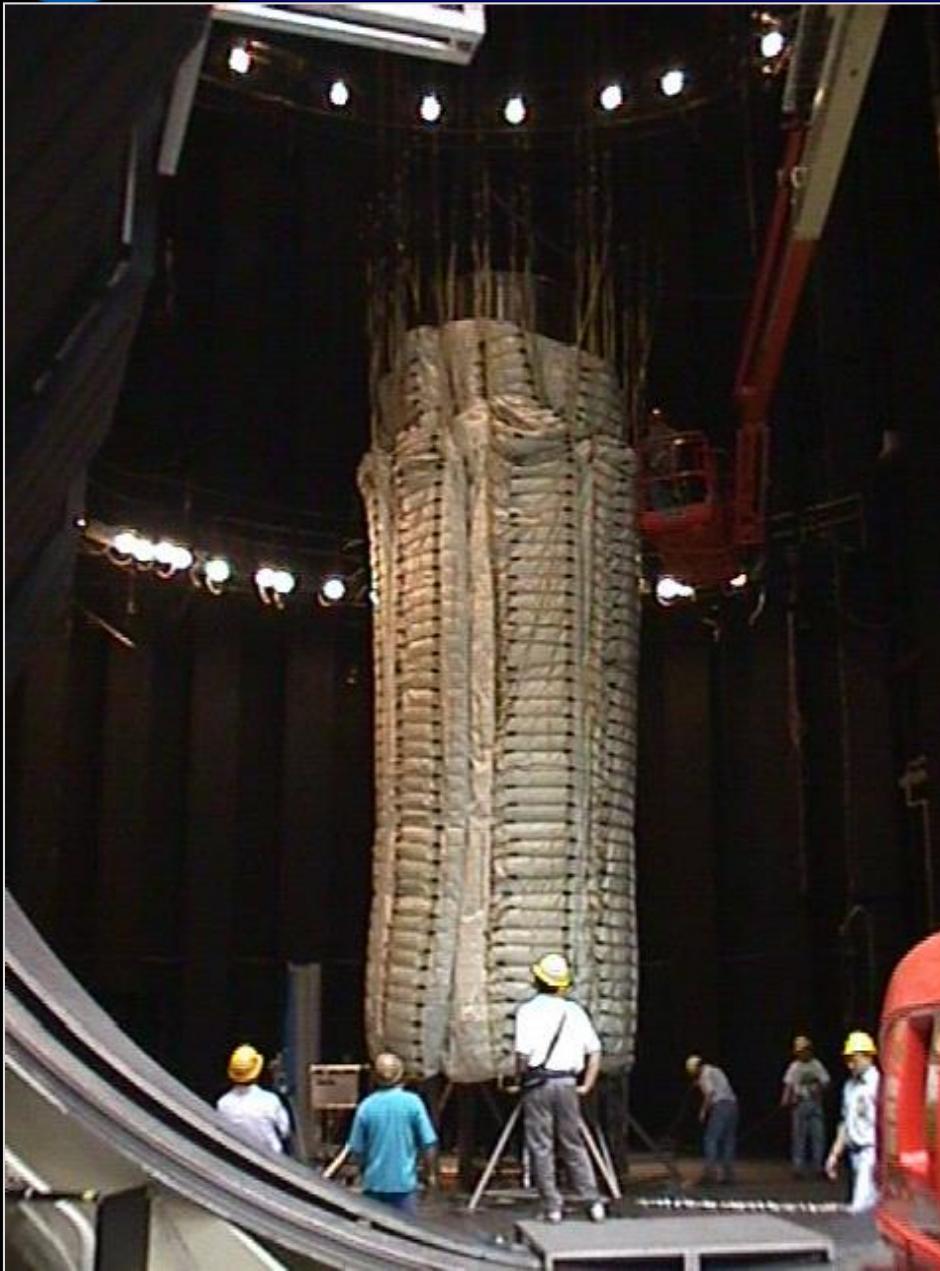


## *SDU-3 Installation of MM/OD Gores*

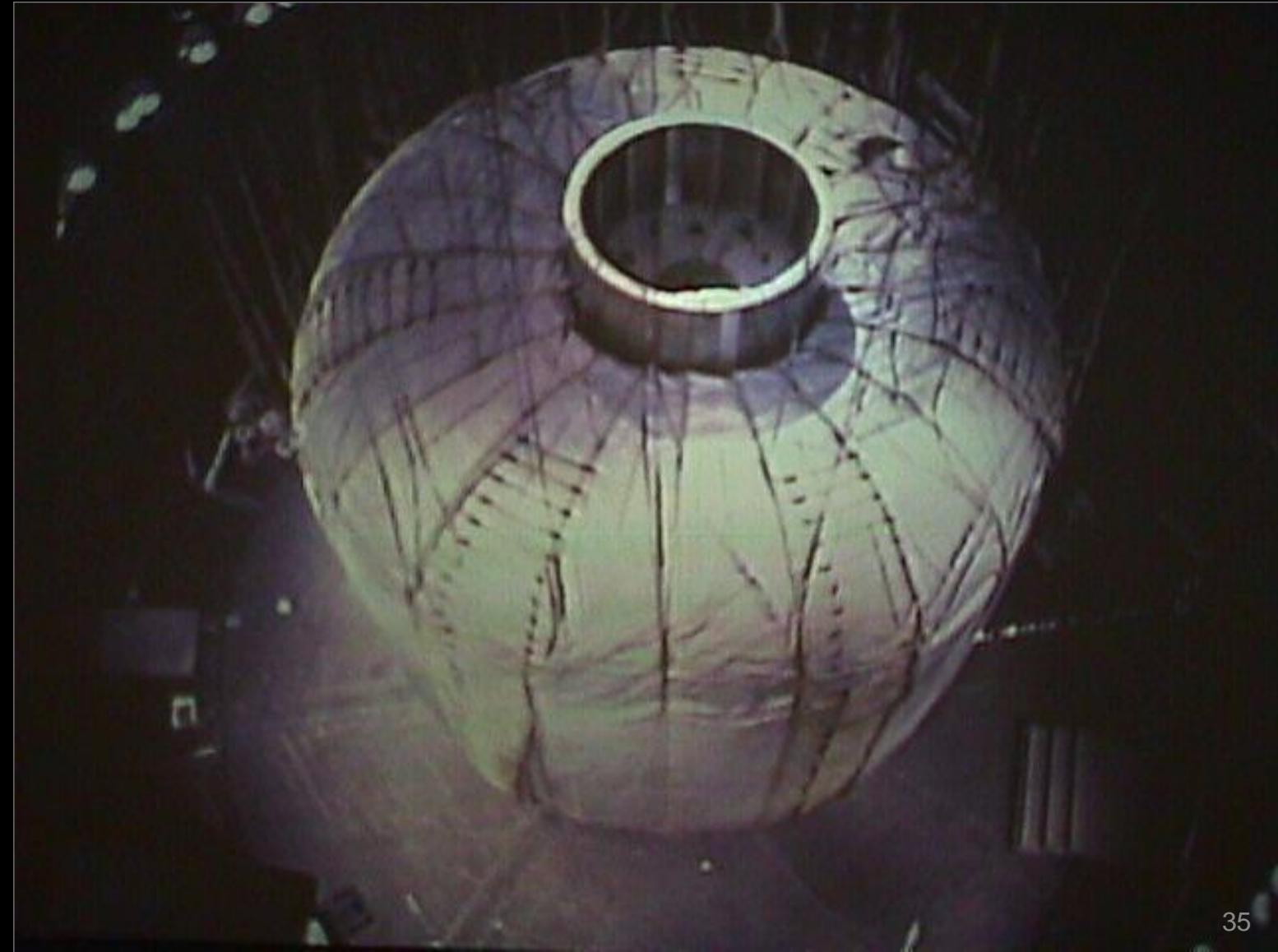


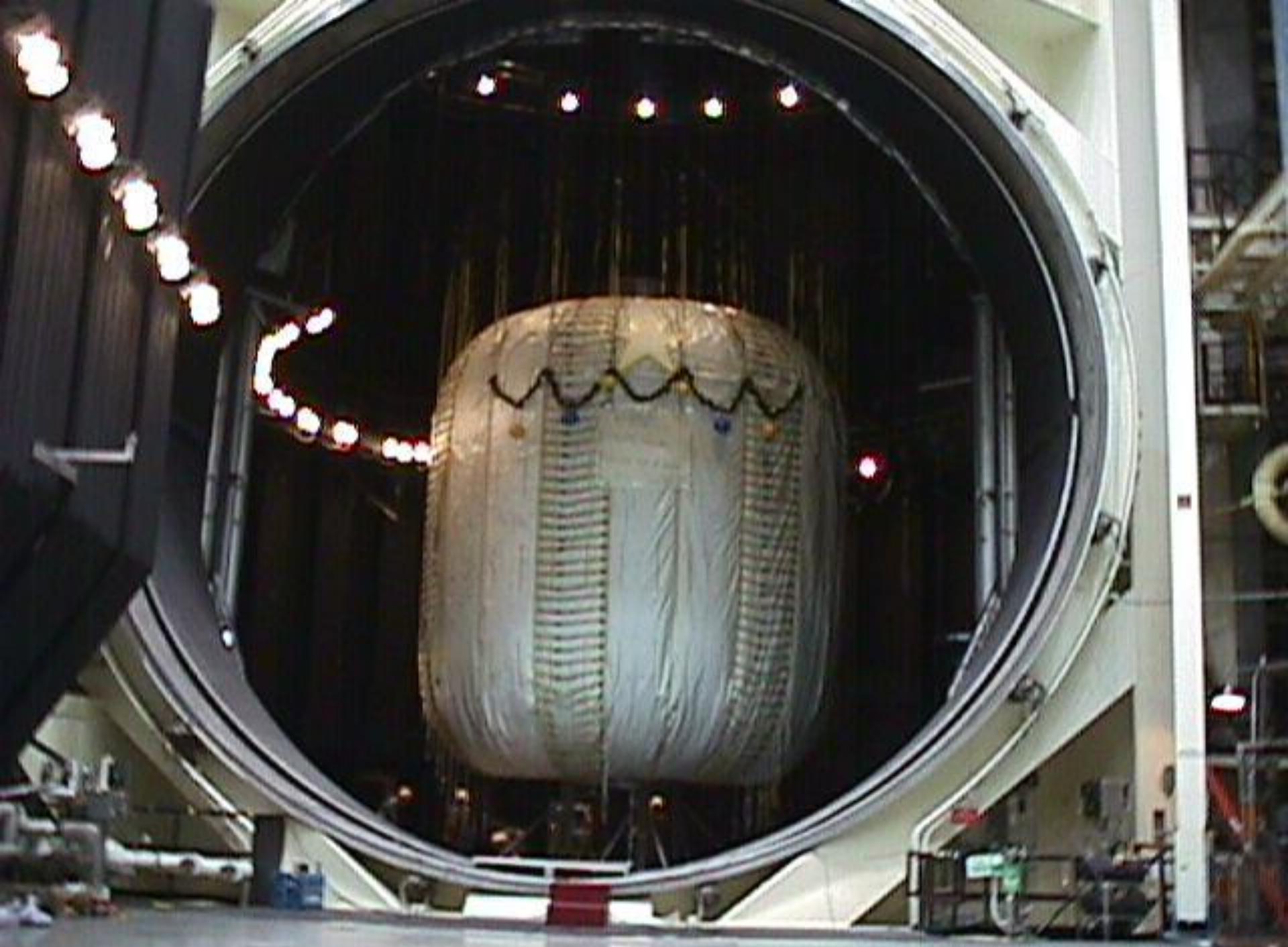


# TransHab Full Scale Shell Development Unit (SDU-3)



Vacuum Deployment Test: December 21, 1998







# Summary

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- TransHab started out as a Mars Transit Habitat (Trans-Hab) tiger team concept in 1997.
- So well liked, we were asked to redesign it as a Govt Furnished Equipment project for an ISS habitat. 1998
- Moved into Rapid design and testing to “proof feasibility.” 1999
- Developed engineering test units, tested 3 important high-risk areas people had concerns with for inflatables. Mitigated the risks.
- Proof-of-Concept that inflatable structures could be used as an alternative for space habitats.
- Revolutionized how the aerospace industry thinks about space habitats.
- Demonstrated “human-centered” design and Human Systems Integration—space architecture.

